THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

JULY, 1952

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SPECIFICATIONS FOR CAST IRON

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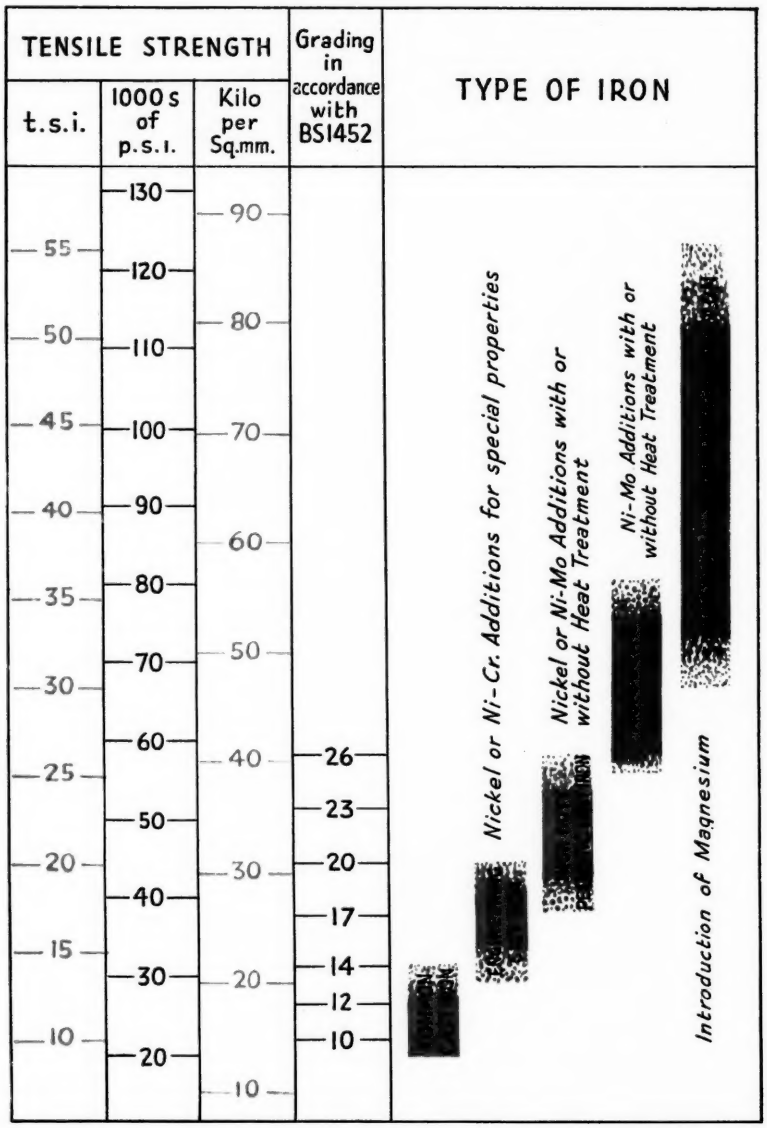
SPECIFICATIONS FOR CAST IRON

This diagram compares various types of cast iron with the grading laid down by British Standard 1452.



Further details of the irons mentioned in the diagram will be found in the following publications: 149—'Nickel Cast Iron for Engineers'; 209—'High Strength Nickel Alloy Cast Iron'; 435—'Nickel Molybdenum Acicular Cast Iron'; 603—'The Engineering Properties and Applications of Spheroidal Graphite Cast Iron'. Copies are available on request.

ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Nickel-containing Spring Materials

M. G. FANGEMANN: 'How to Choose Spring Materials.' *Materials and Methods*, 1952, vol. 35, April, pp. 85-9; May, pp. 112-16.

The first part of the article describes the various types of spring now available; the second deals with the materials used for the respective forms. In the latter connexion the properties and applications of the following materials are discussed: hard-drawn steel, oil-tempered steel, music wire, chromium-vanadium steel, stainless steel (with special reference to Type 302, hard-drawn), clock-spring steel, brass, phosphor bronze, beryllium-copper, Iso-Elastic (nickel 36, chromium 8, molybdenum 0·5, per cent., iron balance), Inconel (nickel 78·5, chromium 14, iron 6·5 per cent.), and Inconel X (nickel 70 min., chromium 14-16, iron 5-9, titanium 2·25-2·75, niobium 0·7-1·2, per cent.). Physical, mechanical, and electrical properties are tabulated, together with the principal uses of the various materials.

See also abstract on p. 174.

'Sigma' Welding of Stainless Steels and Other Materials

See abstract on p. 184.

NICKEL

Nickel, Nickel Alloys and Nickel Compounds: American Chemical Society Symposium

'Nickel Symposium.' *Industrial and Engineering Chemistry*, 1952, vol. 44, May, pp. 949-1027.

The Diamond Jubilee Meeting of the American Chemical Society in 1951 included a symposium (organized by the Division of Industrial and Engineering Chemistry) comprising a survey of the current position of knowledge and development on nickel-containing materials of interest to the chemical industries. The review has particular interest in relation to the celebration of the 200th anniversary of the discovery of nickel by Cronstedt. The scope of the papers is briefly indicated below.

O. B. J. FRASER: 'Developments in Nickel,' pp. 950-4.

Story of the discovery of nickel, followed by an account of the main features of processes which have been used for extraction and refining of the metal from the various types of ore in which it is found. Reference is made, *inter alia*, to recent increases in production capacity and to still further expansion projected by the principal producers: a graph shows world nickel production 1850-1949. The physical constants, thermal properties and electrical and magnetic properties of the pure metal are tabulated. A comprehensive selected *bibliography* gives reference to the main literature dealing with history, occurrence, and extraction of nickel.

A. R. BROSI: 'Isotopes of Nickel,' pp. 955-6.

The eleven known isotopes of nickel have many special properties which make them valuable for a wide variety of chemical studies. In this note the author reviews a few of the general types of application of isotopic techniques to chemical problems, as a preliminary to discussion of the characteristics of individual isotopes. Examples are quoted of the use of nickel isotopes in chemical studies which have been reported in the literature. Among the six radioisotopes of nickel are several which emit very penetrating gamma radiation that can be measured through the walls of heavy process equipment. One radioisotope emits very soft beta radiation, and is suitable for studying reactions of a relatively few atomic layers. Further extension of the use of nickel isotopes is anticipated: work known to be in progress includes their application in diffusion, ion-exchange, and further isotopic-exchange studies.

W. A. WESLEY: 'The Electrochemistry of Nickel,' p. 957-65.

This paper comprises a review of present knowledge, scientific and practical, on the electrochemical reactions of nickel which are utilized in modern industry. An introductory section containing fundamental data on nickel salts is followed by discussion of electrodeposition of nickel, as being the principal step involved in electro-plating, -refining, -forming and -salvaging, and in the preparation of electrotypes and stereotypes. Electrolytes, operating conditions, and the various types of coating which can be produced by electrodeposition are considered: bright nickel baths, and deposition from the all-chloride bath, hard-nickel baths, and other types of special solution are included in the survey. Variation of cathode efficiency with plating conditions is graphically illustrated for four types of solution (hard-nickel, Watts pH 5·5 and 2·0, and a chloride bath), and methods of estimating limiting current density are discussed. The author deals next with the behaviour of soluble nickel anodes, and also discusses applications in which insoluble anodes can successfully be used. Reference is made to work on porosity in electrodeposited nickel, in progress under the auspices of the American Electroplaters' Society; average porosity-thickness relationships in nickel coatings are graphically illustrated. Short notes are given on the two main applications of heavy nickel deposits (electroforming and re-sizing).

Commercially significant nickel-alloy deposits are cobalt-, zinc-, iron-, gold-, and sulphur-zinc-nickel types; phosphorus-nickel and tin-nickel alloy coatings hold promise of development. Information on the

respective types is briefly summarized, and reference is made to proposals which have been made for deposition of heavy layers of a nickel alloy containing up to 35 per cent. of tungsten.

Attention is directed to recent papers on electrorefining of nickel, and an account is given of methods used, in the Research Laboratories of The International Nickel Company, for preparation of spectroscopically pure nickel.

The final main section of the review deals with nickel immersion coatings, giving details of the reactions involved in coating by displacement of nickel by iron and by reduction of nickel salts by hypophosphites. Miscellaneous electrochemical applications of nickel include electropolishing, and gravimetric determination of nickel.

W. Z. FRIEND and F. L. LAQUE: 'Corrosion-Resisting Nickel Alloys and Chemical Progress,' pp. 965-71.

A period of rapid progress in the chemical and process industries has coincided with the commercial development of most of the corrosion-resisting metals and alloys now on the market. Many of these materials contain nickel as an essential element, due not only to the inherent corrosion-resisting qualities of the metal, but to its capacity for alloying with many other elements. In this review the authors present data on the composition and properties of the principal nickel-containing corrosion-resisting materials now in use, grouping them in three classifications:—

(1) *High-Nickel Alloys* (Monel; K, H and S Monels; nickel, low-carbon nickel and Duranickel; Inconel and Inconel X; Hastelloys B, C and D; Chlorimets 2 and 3; Durco D-10; Illium).

(2) *Chromium - Nickel Stainless Steels* (straight austenitic chromium-nickel types; titanium- and niobium-stabilized grades, and molybdenum-containing types).

(3) *Ni-Resist Cast Irons* of five types, for use in varying corrosive conditions, or for heat-resisting purposes, and Minovar, the low-expansion iron containing 34-36 per cent. of nickel.

The characteristics of the respective materials in the three categories are individually discussed and their broad spheres of application are indicated. Reference is also made to the lower-nickel alloy steels having useful application in chemical equipment (e.g., the 3·5 and 5 per cent. types), and to the use of heavy nickel plating in this field.

As an effective method of demonstrating the part played by nickel in the progress of chemical industries, the authors devote the second part of their review to a description of some of the specific uses of nickel-containing materials in the manufacture of various chemical products, including those involving halogens such as chlorine, bromine, fluorine and hydrogen fluoride; synthetic textiles such as viscose rayon, cellulose acetate rayon and nylon; dyestuffs, synthetic plastics (such as phenolics, alkyds, polystyrene and organic chloride polymers); antibiotics (such as penicillin, streptomycin and chloromycetin), fatty-acid products, and corn products.

The review is supported by a *bibliography* of 84 references.

W. D. MOGERMAN: 'Metallurgical Nickel Analysis,' pp. 971-3.

The paper opens with a discussion of difficulties in analysis which delayed general recognition of Cronstedt's discovery of nickel. This is followed by consideration of the methods generally used for determination of small or large amounts of nickel. Sources of error in gravimetric estimation are reviewed.

W. L. TICHENOR: 'Nickel Oxides. Relation between Electrochemical Reactivity and Foreign Ion Content.' pp. 973-7.

The best known electrochemical effects of adding 'foreign' ions to nickel oxides are (1) increase in electrochemical capacity of nickel-oxide electrodes in potassium-hydroxide electrolyte when lithium hydroxide is added to the electrolyte, (2) increase in electrochemical capacity of nickel-oxide electrodes when a small amount of bismuth hydroxide is added to the nickel oxide, and (3) decrease in electrochemical capacity of nickel-oxide electrodes when a small amount of ferric hydroxide is added to the nickel oxide. These effects were discovered by Edison during development of alkaline storage batteries, but although the knowledge has been of considerable importance commercially, little attempt has been made to explain the mechanism of the effects. The present author advances a theory, using the following postulates: Electrolytic oxidation and reduction of nickel oxide are terminated by creation of insulating barrier layers of nickel oxide adjacent to the electronic conductor. 'Foreign' ions, such as those of lithium, bismuth and iron, enter into the crystal of nickel oxide by substitution, replacing nickel ions. The presence of these foreign ions affects the stability of the oxidation states of adjacent nickel ions. This change in stability retards or promotes oxidation of the nickel oxide, and also affects the growth of the insulating barrier layers. Both factors may affect the extent to which the oxide can be oxidized or reduced.

D. A. DOWDEN: 'Catalytic Activity of Nickel: Theoretical Aspects,' pp. 977-85.

A detailed discussion, providing a theoretical basis for study of the electronic factor in heterogeneous catalysis, and showing how it can be used to explain the behaviour of metallic nickel and its alloys when used as catalysts.

J. G. DEAN: 'Nickel Compounds as Catalyst Raw Materials,' pp. 985-90.

Development in the use of nickel catalysts has been rapid since the discovery, by SABATIER, of their efficacy; they are to-day the most widely studied of all catalytic materials. The most familiar, and by far the largest application, is in the hydrogenation of organic materials containing unsaturated carbon-to-carbon bonds. In this function the nickel catalysts belong to the contact type, as used in heterogeneous systems: the nickel is present as part of a solid phase, and the catalyzed reaction takes place in liquid and gas phases, in contact with the surface of the nickel. The process of fat hardening provides an outstanding example of this type of catalysis.

Most of the common nickel compounds have been investigated as catalyst raw materials, but less than a dozen distinct derivatives are now of importance in this connexion. Three inorganic salts, nickel sulphate, chloride and nitrate, serve extensively as intermediates or reagents supplying nickel ion, while nickel oxide, hydroxide, basic carbonate and formate serve as raw materials for the reduction to finely divided active nickel, in the final step of catalyst preparation. Certain nickel alloys, notably the nickel-aluminium types studied by Raney, contain intermetallic compounds which can be made to yield active nickel by selective dissolution of the catalytically inactive constituents, leaving the nickel in the form of an alloy skeleton presenting a very large effective surface per unit weight. This paper contains a detailed discussion of the types of nickel and nickel compounds used, and their treatment in production of catalyst masses; much practical information is given on quantities required for, and costs involved in, preparation of the various types of nickel-containing catalysts, and on quantities of catalyst materials in current use.

A. E. BAILEY: 'Nickel Catalysts in Hydrogenation of Fats and Oils,' pp. 990-4.

Although the amount of nickel used as catalyst in oil and fat hydrogenation is relatively small, the application is an important one. Each pound of nickel so used accounts for the hydrogenation of 2500 to 5000 pounds of oil, and as a catalyst nickel has no known substitute.

This review opens with a historical survey of the development of hydrogenation processes for fats and oils, and gives a succinct account of the main features of the three principal methods used for preparation of nickel catalysts employed in such processes. The problem of poisoning of catalysts is briefly considered.

Nearly all hydrogenation of oils and fats is carried out with a powder form of catalyst: continuous hydrogenation with a massive or stationary catalyst is possible, and was one of the first hydrogenation processes developed, but such a method appears to have inherent disadvantages when applied to the manufacture of edible fats required to meet modern standards of quality. Some notes on methods of using the catalysts are included in this survey.

The final section of the paper deals with composition and characteristics of hydrogenated fat and the relation of catalyst to composition of the fats. Experience to date, and the present state of knowledge, lead to the presumption that development of hydrogenation catalysts will tend to follow developments in fundamental fat and oil chemistry which demonstrate the need for materials capable of promoting or suppressing specific reactions required to produce given results.

C. MCKINLEY: 'Nickel Catalysts in Acetylene and Carbon Monoxide Chemistry,' pp. 995-9.

The author summarizes many of the important applications of nickel as a catalyst in the two fields mentioned, emphasizing the interest of Reppe's work in relation to acetylene chemistry.

In certain salts, such as nickel cyanide, nickel serves uniquely in the polymerization of acetylene to form cyclo-octatetraene, a combination of four molecules of acetylene. Other nickel catalysts will effect the combination of three acetylenic molecules, to form a benzene or substituted benzene structure. Examples mentioned in this review are the formation of trimethylol- and hexamethylol-benzene, benzene and styrene. Nickel serves, not uniquely, but as do other hydrogenation catalysts, in the reduction of double and triple bonds. Bivalent nickel salts catalyze the reaction of acetylene and also of olefins with carbon monoxide and various reactive hydrogen compounds, such as alcohols, mercaptans and water.

M. R. ARNOLD, K. ATWOOD, H. M. BAUGH and H. D. SMYSER: 'Nickel Catalysts for Hydrocarbon-Steam Reaction,' pp. 999-1003.

The authors introduce their paper by a historical survey of development and notes on some of the large-scale plants which are currently employing nickel catalysts for hydrocarbon-steam reactions.

As an indication of the importance of nickel catalysts in such applications, the following statements may be quoted:—

'In 1940 the Hercules Powder Company, at Hercules, California, completed a plant to use natural gas and steam as a source of hydrogen for ammonia synthesis. By 1946 seven plants, with a total capacity of 3 billion cubic feet per month, about three-fourths of the hydrogen then procured by the reaction of hydrocarbons with steam over nickel catalysts, were using hydrogen from natural gas for ammonia synthesis. In 1949 about 40 per cent. of the hydrogen for ammonia synthesis was produced from methane and steam, whereas to-day over 80 per cent. of the American capacity for synthetic ammonia is, or soon will be, in thirteen plants using this reaction, over nickel catalysts. As a result of the conversions now in progress in the synthetic ammonia industry more hydrogen soon will be produced in the United States by reacting hydrocarbons with steam over nickel catalysts than will be produced by all other methods combined. Hydrogen from hydrocarbons, exclusive of that used in ammonia synthesis gas, is produced for use in methanol synthesis, the hydrogenation of vegetable oils, the hydrogenation of petroleum, and other hydrogenations and syntheses. The Bureau of Mines has operated a pilot plant producing synthesis gas for the Fischer-Tropsch reaction by reaction of natural gas with steam and carbon dioxide over nickel catalysts, and this process is believed to have industrial application in the future.

'It is estimated that about 400,000 pounds per year of nickel catalysts would be required to keep the production for all purposes from hydrocarbons and steam at the present volume, representing a nickel consumption of about 80,000 pounds per year.'

The commercial catalysts used in this field are either supported on a refractory material or compounded and shaped by extruding or tabletting: nickel contents are between 4 and 30 per cent. They are used at temperatures of 1300°-1800°F. (705°-980°C.) and at pressures between atmospheric and 15 p.s.i.

The experimental work reported in this paper is part of a programme of laboratory investigation on the

properties of catalysts for the reaction of hydrocarbons with steam. Study of life and activity of various types of catalyst shows that, in general, catalysts of higher nickel content tend to have higher activity than those in which the nickel percentage is lower, but that other factors are also operative in determining activity. Rapid inactivation of commercial catalysts occurs above 1900°F. (1035°C.). Further stages of the programme will cover investigation of surface area, porosity, pore size and particle size, as affecting efficiency of catalysts for hydrocarbon-steam reactions.

C. K. HANCOCK: 'Raney Nickel-Catalyzed Hydrogenation of Commercial Aldol,' pp. 1003-6.

Catalytic hydrogenation of aldol is one step in one of the processes for synthesizing butadiene from natural gas. This paper reports a study of operating conditions as affecting efficiency. Under optimum conditions the commercial aldol used in the experiments yielded about 70 per cent. butylene glycol, with alcohol as the main by-product. At temperatures higher than those found to give best results increased dehydration of aldol preceded hydrogenation, and led to increase in yield of butyl alcohol. Addition of water in amounts up to 30 per cent. does not greatly affect the yield of butylene or the time required for the reaction. The catalyst used was Raney nickel, prepared by the method of COVERT and ADKINS (*Jnl. Amer. Chemical Soc.*, 1932, vol. 54, p. 4116): 5 grams of Raney nickel per 100 grams of charge proved to give best results. By means of special protective procedure, which is described, it is possible to re-use the catalyst.

R. PAUL, P. BUISSON and N. JOSEPH: 'Catalytic Activity of Nickel Borides,' pp. 1006-10.

The authors report that by reaction of sodium or potassium borohydride with various nickel salts, under various conditions of temperature and pH, and with a variety of solvents, voluminous black precipitates are produced, which invariably contain one atom of boron to two atoms of nickel. These products are neither magnetic nor pyrophoric, and in hydrochloric acid or potassium triiodide do not dissolve as quickly as Raney nickel.

A study was made of the catalytic activity of the nickel borides, in comparison with that of Raney nickel, in the hydrogenation of safrole, furfural, and benzonitrile. When prepared from nickel acetate or nickel chloride these catalysts have an activity equal, or slightly inferior, to that of Raney nickel: they are characterized by high resistance to fatigue. In further experiments, alkaline borohydride was reacted with nickel-salt solutions containing small amounts of metals known to promote activity (e.g., chromium, molybdenum, tungsten, vanadium, cobalt, manganese, or iron). Complex catalysts so prepared yielded some types which proved to be distinctly more active than Raney nickel. It is suggested that the simplicity and rapidity of this technique of preparation renders it highly suitable for use in studying the action of promoter substances.

Although this paper is restricted to experiments on nickel-boride catalysts, the authors report that experimental work has demonstrated the suitability of the technique for production of cobalt boride. Such catalysts are less active than the nickel-base types, but their activity may be increased by addition of promoters, particularly chromium, molybdenum, or tungsten.

R. H. GRIFFITH: 'Catalytic Oxidation of Organic Sulfur Compounds in Coal Gas,' pp. 1011-14.

Sulphur compounds normally present in coal gas are carbon disulphide, carbon oxysulphide, and thiophen: there may also be traces of thiols and other more complex substances. With some coals currently in use total sulphur content of the coal gas may be as high as 50 grains per 100 cubic feet.

Reference is made to the early work of CARPENTER (1913) in establishing the possibility of using a catalytic process for decomposition of sulphur-bearing compounds, employing a nickel subsulphide catalyst, and to the use of this process in the works of the South Metropolitan Gas Company, London. Due to the high expense involved, it was not widely adopted in industry, but as a result of later experiments a modified process was developed and has been extensively used by the North Thames Gas Board. A detailed description is given of this method, which involves oxidation of the organic sulphur compounds by contact with a nickel subsulphide catalyst, in the range 220°-370°C. A plant operating this process, and treating 1,500,000 cubic feet of gas per day, has been working for 14 years: it is operated by automatic addition of air, controlled from a magnetic oxygen analyzer. Thiophen is not decomposed in this process, but other sulphur compounds present are reduced to about 2 grains per 100 cubic feet of gas. For use on consumers' premises where low-sulphur gas is not available, small catalytic units working by the same method have proved useful, for example, in preparation of reducing atmospheres for controlled heat-treatment of metallurgical products. A typical small catalytic plant is described.

Plans recently completed for a plant which will have a treatment capacity of 15,000,000 cubic feet of gas per day embody improvements in design and operation which will decrease running cost: estimates show that desulphurization will add less than 2 per cent. to the cost of distributed gas.

C. G. HARMAN and B. W. KING: 'Applications of Nickel Compounds in Ceramics,' pp. 1015-17.

A highly condensed summary: the main points discussed are indicated below:—

A large proportion of the nickel consumed by the ceramic industry is in the form of oxides or sulphates, the utility of which is based on certain clearly defined inherent properties. Nickel oxide has the ability to absorb light selectively, as, for example, when the oxide is used to produce coloured glass or a coloured pigment: the oxide is also used as an addition to groundcoat enamels, as a means of promoting a better bond between the glass and the metal. The

sulphate is utilized in 'nickel-dip' baths, employed for treatment of iron prior to enamelling: a considerable literature confirms the beneficial effect, on adherence, of the nickel-flashing procedure.

A later development in the ceramic industry is that of the 'ferrites' for use in electrical equipment. In these materials nickel oxide is used as a means of improving magnetic and electrical properties. With regard to metallic nickel, the chief interest in this industry lies in ceramic-metal composites, in which it is hoped to produce a combination of the good qualities of both constituents. In this connexion studies on nickel-alumina and other cermets have been reported. Nickel-containing alloys play an important part in the processing of ceramic materials, e.g., in electrical resistors and other furnace parts, in thermocouples, and in equipment in which corrosion-resisting qualities are required.

N. M. MACKENZIE, H. E. MILLSON and B. L. WEST: 'Nickel Derivatives of Azo Dyes,' pp. 1017-23.

Certain nickel derivatives of azo dyes show outstanding fastness to light, as dyes and pigments. The patent literature contains numerous references to the use of such compounds as wool dyes, direct dyes, pigments, dyes for synthetic fibres, leather colours, and colours for lacquers and plastics. The present authors give some tabular comparisons of the colour and fastness properties of nickel and of chromium complexes. Chromium and copper co-ordination compounds have found important commercial application, but the nickel derivatives are not yet extensively used on an industrial scale. It is considered, however, that, in view of the increasing application of colour to various fibres and materials of construction, certain of the nickel azo dyes are potentially useful.

J. J. VERBANC: 'Nickel Compounds in Elastomers,' pp. 1023-7.

Nickel compounds have not yet been extensively used in compounding elastomers, but the author of this paper discusses some new and unusual applications, dealing with nickel compounds as polymerization chemicals, their use in vulcanization processes, as elastomer stabilizers, and as activators for elastomer peptization. The effects producible by the nickel compounds appear to be specific to these materials, since corresponding compounds of other metals which have been tested are either inert or only slightly effective. Nickel salts of xanthates and dithiocarbamates are the most interesting in this industry, and of these types nickel dibutyldithiocarbamate appears to hold the greatest promise of useful application.

The particular form of activity shown by nickel dibutyldithiocarbamate depends upon the elastomer in which it is used. In GR-S it retards the rate of absorption of oxygen by the unvulcanized polymer and increases the resistance of vulcanizates to cracking when exposed to ozone. When used in neoprene vulcanizates it increases their heat-resistance, retards discolouration under the action of light, and assists in retarding liberation of hydrogen chloride under the influence of heat, light, and oxygen. In natural rubber, when used in conjunction with softening agents, such as the aryl mercaptans, it is a strong promoter of the important process of plasticization. The commercial utility of nickel dibutyldithiocarbamate is limited by its colour and by its action in increasing the rate of deterioration of natural rubber vulcanizates by oxygen.

Catalysts: Recent Developments: Nickel Catalysts

W. G. FRANKENBURG, V. I. KOMAREWSKY and E. K. RIDEAL: 'Advances in Catalysis, Vol. III.' *Published by Academic Press, Inc., New York*, Apr., 1951; 360 pp. Price 25/-.

This book is one of a series designed to familiarize a wider public with the present state of catalytic chemistry, by presenting authoritative reports from specialists in various fields of catalysis and related subjects.

Restrictions on Use of Nickel: O.E.E.C. Action

'O.E.E.C. Agrees on Restricted Use of Non-Ferrous Metals.' *Board of Trade Jnl.*, 1952, vol. 162, May 31, p. 1095.

Further steps have been taken by the Council of the Organization for European Economic Co-operation to restrict the use of certain non-ferrous metals, shortages of which are causing concern to European manufacturers. At the same time the Council has reviewed the success of measures put into effect last year.

In the case of nickel, nickel alloys and nickel plating, the Council decided that Member countries should prohibit their use in the manufacture of nearly 500 commodities, ranging from domestic appliances to machinery and motor vehicles. Member countries will be entitled to grant exemption to those measures in certain cases for their home markets, to allow manufacturers to dispose of stocks, and to maintain trade with non-member countries. The export to Member countries of commodities on the list which contain nickel in prohibited quantities is banned. A number of countries have already put these measures into effect.

Member countries will also in future take all possible steps to prohibit the manufacture or use of case-hardening and constructional steels containing more than a certain percentage of nickel and molybdenum (in this connexion see also *Nickel Bulletin*, 1952, vol. 25, No. 5, pp. 125-7). Exceptions to this prohibition will be allowed under circumstances similar to those permitted in the case of nickel and nickel alloys.

Magnetostrictive Properties of Nickel and Nickel-Iron Alloys

J. C. COOK: 'An Apparatus for Determining both the Dynamic and Static Magnetostrictive Properties of Rods of Ferromagnetic Materials under Various Polarizing Fields and at Various Temperatures.' *Nuovo Cimento*, 1950, vol. 7, pp. 192-7 (Suppl. No. 2, 1950); *Physics Abstracts*, 1952, vol. 55, May, Abs. No. 3753).

Description of electronic ultramicrometer, employing the frequency change arising from varying a capacity by the strain of the specimen, to study the magneto-strictive properties of rods of 36 per cent. nickel

nickel-iron alloy, and of cold-drawn, annealed, quenched, and hot-rolled nickel. For brief summary of results, see *Physics Abstracts, loc. cit.*

Nickel in Magnetostrictive Delay Line

'Magnetostrictive Delay Line.' *Research*, 1952, vol. 5, June, pp. iii-iv.

Short note on delay line by Ferranti, Ltd., developed primarily to generate and to detect pulses separated by an accurately determined time period, in connexion with a 1,000 Mc/s distance-measuring apparatus. The delay line has also other possible applications. Its operation, which is briefly described, is based on the magnetostrictive properties of nickel.

Influence of Impurities on Initial Permeability of Nickel-Iron Alloys

See abstract on p. 175.

Determination of Traces of Nickel and Other Metals in Oils

E. L. GUNN and J. M. POWERS: 'Ash Residues from Petroleum Catalytic Cracking Feed Stocks; Spectrochemical Analysis.' *Analytical Chemistry*, 1952, vol. 24, Apr., pp. 742-6.

The authors describe a sensitive and rapid method developed as an aid to the evaluation of the influence of trace metals on the refining, processing and utilization of petroleum. The method is employed primarily for inspection of catalytic cracking stock, to determine the presence of trace metals which may affect catalytic activity, but is also applicable to routine determination of trace metals in oils other than catalytic feed stocks.

The oil sample is ashed and the residue is analyzed by a common-matrix spectrochemical method. Three milligrams of ash are sufficient for analysis and the time required for determining nine metals is less than three hours. Full details of procedure are given for estimation of iron, sodium, calcium, aluminium, magnesium, silicon, nickel, chromium and vanadium.

Determination of Nickel in Lead

A. S. ANDREEV *et al.*: 'Determination of Small Amounts of Nickel Impurity in Lead and the Active Masses of the Lead Accumulator.' *Jnl. Anal. Chemistry, U.S.S.R.*, 1951, vol. 6, pp. 375-82.

Essential details of the method are given in *British Abstracts C*, 1952, Apr., p. 143, Abstract No. 1084.

Nickel-containing Spring Materials

See abstract on p. 174.

Heat-Content Measurements on Nickel Chloride

J. P. COUGHLIN: 'High-Temperature Heat Content of Nickel Chloride.' *Jnl. Amer. Chemical Soc.*, 1951, vol. 73, Nov., pp. 5314-15.

Heat-content measurements were made over the range 298·16 to 1336°K. (25·16 to 1062°C.). Temperature and heat of fusion were evaluated. A table of heat content and matching entropy increments above 298·16°K. is included.

ELECTRODEPOSITION AND OTHER COATING METHODS

Nickel+Chromium Plating of Bumpers

D. H. SCHANTZ: 'Advantages of Simplicity in the Electroplating of Automobile Bumpers.' *Proc. 38th Ann. Convention, Amer. Electroplaters' Soc.*, 1951, pp. 67-72; disc., pp. 72-3.

The paper gives full details of the cycle of preparation, plating, and finishing used in the works of Michigan Bumper Corporation: the record is based on five years' experience. Particular emphasis is laid on the elimination of all unnecessary steps and the avoidance of complicated plating layouts, which have become, in the author's view, an undesirable feature of modern practice. Attention is directed to the intentional omission of copper undercoating, although copper was in plentiful supply when the schedule was drawn up. It is believed that the simplicity of the process in practice far outweighs any theoretical cost advantage to be obtained by substituting copper for part of the nickel. Some of the main features of the process used are summarized below:—

Cleaning: two-stage electro-cleaning is standard, and much attention is given to efficiency in spray rinsing.

Anodic acid treatment: This form of treatment, under somewhat varying conditions, is now generally employed in shops plating bumpers. Best results have been obtained on hot-formed bumpers by maintenance of the acid at 65-70 per cent. by vol. of 66°Bé sulphuric acid: temperature 80°-100°F. (27°-38°C.): current density about 60 amp./sq. ft. (6·5 amp./sq. dm.): time about 1½ minutes. It is stated that in the five years' experience with this anodic sulphuric-acid treatment no trouble has been experienced with poor adhesion of the nickel plating, and, in addition, it is found that such treatment has a slightly levelling action, although the bath is not a true electropolishing solution.

Nickel plating: Initially a Watts-type bath was used, but this was later discarded in favour of a cobalt-nickel semi-bright solution. The coating deposited from this solution buffs more easily than the Watts-type nickel, and the use of the cobalt-nickel bath has also increased plating capacity, in that a higher current density can be used without increase in voltage, due to the higher operating temperature. Air agitation was at first considered of doubtful advantage, but experience has shown that it helps to prevent roughness. Cost of operating the bath, and nickel-salts consumption, have proved low, and during the period in which two 6,000-gallon tanks have been operated it has not been found necessary to raise the pH or perform any batch treatment. Trials with anode bags of cotton duck, Nylon and Vinyon have led to standardization of Vinyon, which gives long life and has efficient filtering characteristics. The bath is operated at relatively low pH (2·3 preferred; 2·9 possible): a temperature of 160°F. (71°C.) is satisfactory, but normally 170°-175°F. (76°-80°C.) is maintained.

After a salvage rinse the bars are cold- and then

hot-rinsed, the latter bath being kept alkaline to phenolphthalein by means of borax. The nickel coating is buffed and the bumpers are then chromium plated. The bath used is a standard sulphate solution with a chromic-acid concentration of 35 oz./gal. (260 g./L.). In periods of chromic-acid shortage a concentration as low as 22 oz./gal. (165 g./L.) has been successfully used.

Pre-Plated Nickel-Coated Steel Wire

H. KENMORE: 'Pre-plated Drawn Steel Wire Saves Scarce Metals.' *Materials and Methods*, 1952, vol. 35, May, pp. 96-8.

The writer urges the advantages of wire produced by the Kenmore process, in which a heavy coating of the desired metal (e.g., copper or nickel) is electrodeposited on the steel core and the plated wire is drawn to size by conventional methods. It is claimed that wire so produced can be further shaped and worked by bending, flattening, swaging, and even thread-rolling operations, without chipping or flaking of the coating. The nature of the bond produced and maintained in copper-plated wire is illustrated.

Nickel-coated steel wire produced by the Kenmore process has been used for various spring products, and also for typewriter-key levers. For closely coiled helical springs it is claimed to have special advantages, since by using pre-plated wire the whole spring is uniformly coated. Other typical applications of steel wire pre-plated with nickel include lead wire, incandescent and fluorescent lamp wire, and headlight wires for automobile lamps. Nickel has also been pre-plated on copper wire for ordinary and high-power tube leads used in radio apparatus, and for conductors operating at elevated temperatures. It is also stated to be particularly suitable in appliances embodying asbestos-covered conductors for special heaters, and high-wattage lamps. Conductivity of the nickel-plated wire is about 95 per cent. of that of copper.

Restrictions on Use of Nickel: O.E.E.C. Action

See abstract on p. 171.

NON-FERROUS ALLOYS

Monel Staybolts in British Railways Tank Engines

'British Railways Class '3' Standard Tank Engine.' *Railway Gazette*, 1952, vol. 96, May 23, pp. 577-8.

The building of the first of a new standard class '3' 2-6-2 tank engine has now been completed at the Swindon works of the Western Region, British Railways. The tractive effort of the new type is 21,490 lb., as compared with 25,100 lb. for the class '4'. Like the class '4', both tender and tank types, the class '3' has almost universal availability over main and secondary lines throughout Britain, and is designed to replace various tender and tank engines of similar power classification now becoming obsolete. As in various other classes of engine being built under the B.R. standardizing programme, all the firebox water-space stays in the new class '3's' are of Monel, fitted with steel nuts inside the firebox. Roof, longitudinal, and transverse stays are of steel.

Spot Welding of Monel Sheet for Steam Traps

'Spot Welding Monel Sheet.' *Metal Industry*, 1952, vol. 80, May 16, p. 405.

The note describes methods used for spot-welding of Monel sheet used in the diaphragm of an expansion-type thermostatic element embodied in a steam trap: the diaphragm is made up of two pressings from 0·006-in. Monel sheet, joined with a gas-tight seal. Attempts to join the pressings by resistance welding were at first unsuccessful, and consideration was given to the use of material of heavier gauge, which would be easier to weld. Some success was obtained with 0·008-in. Monel sheet, but trouble was experienced with the electrodes, which 'mushroomed' or built up with Monel, and thus required frequent repointing. This problem appeared to rule out the use of resistance welding under production conditions, but success has now been achieved by the use of a 4-kVA electronically controlled spot-welder manufactured by The General Electric Company, Ltd. This machine was designed in the G.E.C. laboratories, for their own use in welding very thin wire and sheet, for which work no suitable equipment was on the market. The machine is illustrated.

Structure and Properties of Complex Nickel-Aluminium Bronzes

M. COOK, W. P. FENTIMAN and E. DAVIS: Observations on the Structure and Properties of Wrought Copper-Aluminium-Nickel-Iron Alloys.' *Jnl. Inst. Metals*, 1952, vol. 80, Apr., pp. 419-29: Paper 1364.

Increasing interest is being shown by engineers in wrought complex aluminium bronzes containing appreciable amounts of nickel and iron: this paper presents information on structure, hardness and tensile properties of alloys within the ranges aluminium 8-12, nickel 4-6, iron 4-6, per cent.

For the preliminary investigations ingots weighing 10 lb. each were cast and hot-rolled into strip 0·30 and 0·10 in. thick. The first part of this section of the report is concerned with the structure of the alloys under equilibrium conditions between 1000° and 500°C.; the second deals with structural changes which occur when the alloys are brought into equilibrium at 1000°C. and subsequently tempered between 300° and 900°C. for periods up to 256 hours; the third covers a study of the mechanical properties of representative alloys, both as-quenched after bringing into equilibrium at various temperatures, and after various tempering treatments following quenching from 1000°C. The properties are correlated with the structural changes reported in the earlier sections.

As a result of these preliminary studies, six alloys were selected for processing on a larger scale: observations on the effects of hot- and cold-rolling and subsequent treatments are reported, and the properties of extruded rod were investigated.

In these complex alloys four phases, α, β, δ and $\varkappa$ were identified, having, respectively, random

face-centred cubic, random body-centred cubic, γ-brass type, and ordered body-centred cubic structures. The phase fields for equilibrium conditions were approximately determined. Structurally the alloys can be divided into three classes: (1) those containing 8-9 per cent. of aluminium, which, consisting at 1000°C. of α and β, change at lower temperatures to α and κ; (2) alloys containing 10 per cent. of aluminium, which consist of β at 1000°C., of α, β and κ between 800° and 900°C. and of α and κ at lower temperatures; and (3) alloys containing 11-12 per cent. of aluminium, which consist of β at 1000°C., change from β+κ to α+β+κ over the range 800° to 600°C. and finally change to α+κ+δ.

In examining the mechanical properties the range of composition selected was nickel and iron 5-6 per cent. each, with 8·5-10·5 per cent. aluminium. The investigation was confined to consideration of the structural features and mechanical properties of such materials in the conditions obtained by the normal industrial operations of hot- and cold-rolling, etc. Properties of five alloys within the above range were determined in the quenched, quenched-and-tempered, hot-rolled, and hot-rolled and annealed conditions. In general, optimum properties were obtained in the alloy containing aluminium 10, nickel 5, iron 5, per cent., for which a considerable amount of data is recorded. Structure and properties of extruded rod were determined on two alloys of the nominal composition aluminium 10-10·5, nickel and iron each 5·0-5·5 per cent., and the influence of annealing on the extruded rod was studied.

Estimation of Nickel in Copper-base Alloys

N. M. SILVERSTONE and D. W. D. SHOWELL: 'Determination of Iron, Nickel and Manganese in Copper-base Alloys.' *Metal Industry*, 1952, vol. 80, June 6, pp. 467-9.

The note describes methods developed in the laboratories of the Birmingham Battery and Metal Company, Ltd., as a result of investigations designed to ensure accuracy combined with greater rapidity than is possible by standard procedures. The work was designed primarily to improve methods for use with the 93:5:1·5:0·5 per cent. copper-nickel-iron-manganese alloy, but subsequent investigation showed the new procedures to be applicable to the general range of copper-base alloys. The three elements may be determined individually (full details are given), but the authors also describe a composite scheme, according to which suitable aliquots are taken from a master solution, so that all three elements may be estimated on a single sample.

Nickel-containing Spring Materials

F. P. ZIMMERLI: 'The Metals Used for Mechanical Springs.' *Metal Progress*, 1952, vol. 61, May, pp. 97-106.

A review of the composition of ferrous and non-ferrous spring materials, the properties of the respective types, and their individual spheres of application. Typical low- and high-alloy spring steels are discussed, also copper-base alloys (phosphor bronze, beryllium-copper, silicon bronze or 'spring bronze', and nickel silvers).

Attention is directed to the importance of several nickel-base alloys in spring applications, particularly in those involving resistance to corrosive attack and/or high-temperature conditions. Properties of spring-temper grades of the following materials are given: Monel, Inconel and Inconel X, K Monel, Duranickel, and Permanickel. The significance of the constant-modulus alloys Elinvar and Ni-Span C in the spring industry is emphasized, and details are given of the composition of the Elgiloy and Cobenium watch-spring alloys, containing high percentages of cobalt, nickel and chromium, with substantial additions of molybdenum.

See also abstract on p. 167.

Sigma Phase in Nickel-Vanadium Alloys

W. B. PEARSON: 'Transitions in the Chromium-Manganese and Nickel-Vanadium Sigma Phases.' *Nature*, 1952, vol. 169, May 31, p. 934.

Transitions have been observed in the chromium-manganese sigma phase at 1005°C. and in nickel-vanadium sigma phase at a temperature below 800°C. (*ibid.*, 1952, vol. 169, Jan. 12, p. 70). Investigation of the structure present in both systems above the transition temperature shows that the same main X-ray reflexions are given by the high-temperature phase as are observed at room temperature. Alloys quenched from the high-temperature-phase regions do not show decomposed microstructures. It is considered that the transitions may be of the order-disorder type.

Nickel-Chromium Equilibrium Diagram

D. S. BLOOM and N. J. GRANT: 'Chromium-Nickel Phase Diagram.' *Jnl. of Metals*, 1952, vol. 4, May (*Trans. Amer. Inst. Mining and Metallurgical Engineers*), pp. 523-4; T.P. 3305E.

Discussion on paper *ibid.*, 1951, vol. 3, pp. 1009-14; see *Nickel Bulletin*, 1952, vol. 25, Nos. 1 and 4, pp. 9-10 and 104.

P. DUWEZ and H. MARTENS expressed the opinion that the results obtained by the authors lead to such drastic departure from the generally accepted chromium-nickel diagram as to make it desirable that additional data should be accumulated before it is considered as correct. Observations which they report are not in agreement with those reported by BLOOM and GRANT.

P. R. KOSTING drew attention to the possible introduction of discrepancies through variation in the purity of the chromium used by different investigators.

NICKEL-IRON ALLOYS

Isothermal Formation of Martensite in Nickel-Iron Alloy

E. S. MACHLIN and M. COHEN: 'Isothermal Mode of the Martensitic Transformation.' *Jnl. of Metals*, 1952, vol. 4, May (*Trans. Amer. Inst. Mining and Metallurgical Engineers*), pp. 489-500; T.P. 3260 E.

The phenomenon of isothermal martensite transformation has been established as the result of various

recent investigations, to which the authors give reference. The existence of such isothermal transformation has been claimed to confirm the nucleation and growth hypothesis as applied to the martensite reaction, but it has been pointed out that isothermal transformation of a martensitic phase is also compatible with reaction-path description of the transformation. The purpose of the investigation reported in this paper was to examine the isothermal mode of the martensitic reaction, both theoretically and experimentally, in order to test the validity of the two theories.

The alloy used contained about 71 per cent. iron and 29 per cent. nickel: the amount of isothermal transformation was determined by electrical-resistance measurements. The results, which are presented in detail, and are critically discussed in the light of relevant literature, show that isothermal formation of martensite in an alloy of this type takes place mainly by the nucleation of new plates, rather than by the growth of existing ones, and that it is dependent on time and temperature of isothermal treatment, the amount of athermal martensite* present, the state of internal strain, and the application of tensile stress. The conclusion is reached that the isothermal nucleation is activated by thermal fluctuations superimposed on localized regions of very high strain.

It is considered that the reaction-path concept, involving martensite nucleation at strain embryos by athermal activation on cooling, or by thermal fluctuations on holding, reconciles the athermal and isothermal modes of transformation, and offers a unified picture of the kinetics of martensite formation.

Magnetostrictive Properties of Nickel and Nickel-Iron Alloys

See abstract on p. 171.

Burst Phenomenon in Martensitic Transformation

E. S. MACHLIN and M. COHEN: 'Burst Phenomenon in the Martensitic Transformation.' *Jnl. of Metals*, 1952, vol. 4, May (*Trans. Amer. Inst. Mining and Metallurgical Engineers*), pp. 519-20: T.P. 3305E.

Correspondence on paper published *ibid.*, 1951, vol. 3, Sept., pp. 746-54: see abstract in *Nickel Bulletin*, 1951, vol. 24, No. 11, pp. 235-6. H. SUZUKI and T. HOMMA presented data indicating that the burst temperature in the iron-nickel alloys varies in a characteristic manner with nickel content and that the phenomenon reported by the original authors is not an isolated case. The mode of propagation of martensite in these alloys is discussed at some length.

Permalloy F

'A High Permeability Nickel-Iron Alloy.' *Engineer*, 1952, vol. 193, June 6, p. 775.

The method of domain orientation has been used in the production of a new type of nickel-iron alloy, 'Permalloy F', which is characterized by a markedly rectangular hysteresis loop and low coercive force. This material, placed on the market by Standard Telephones and Cables, Ltd., is stated to be very suitable for all forms of saturable reactor: it is supplied in the form of fully heat-treated toroidal cores wound from thin tape. Diagrams show the d.c. hysteresis loop of Permalloy F (thickness 0·002 in.) and illustrate the d.c. and a.c. magnetization properties of the alloy. It is indicated that a flux density of nearly 14,000 gauss may be obtained in magnetizing fields of less than 0·1 oersted. The hysteresis loop shows that from a maximum flux density of 13,500 gauss the remanence is greater than 13,000 gauss, while the coercive force is less than 0·05 oersted, resulting in a hysteresis loss of only 210 ergs. The specific gravity of the alloy is 8·4 and its electrical resistivity is 26 microhms per centimetre cube. Details are given of core sizes which are now available: for very small cores for memory circuits and computers other sizes will be standardized as need arises.

*Martensite present in quenched steel prior to isothermal treatment.

Influence of Impurities on Initial Permeability of Nickel-Iron Alloys

M. KERSTEN: 'The Effects of Impurities on Initial Permeability.' *Zeitsch. für physikalische Chemie*, 1951, vol. 198, Nos. 1-4, pp. 89-106.

Recent developments in the theory of ferromagnetic hysteresis are applied by the author to a discussion of initial permeability of pure and slightly impure ferromagnetic materials, including iron, nickel and nickel-iron alloys. Initial permeability of iron is much more sensitive to the presence of impurities than that of nickel or nickel-iron alloys containing more than 40 per cent. of nickel. A formula is derived which gives theoretical values for initial permeability of the three materials, and the respective lowering of the values caused by small amounts of impurity.

Magnetostriction in Nickel-containing Magnet Alloys

M. MCCAIG: 'Temperature Variation of the Magnetostriction of 'Alcomax'.' *Nature*, 1952, vol. 169, May 24, pp. 889-90.

Brief note, giving results of some preliminary measurements of magnetostriction, as a function of temperature (0°-800°C. approx.) in Alcomax and Ticonal, nickel - aluminium - iron - base alloys. Magneto - striction was measured in a field of about 1,500 oersted, using an adaptation of Honda's rotating-mirror method. In Alcomax a sharp fall in magneto-striction is observed at temperatures from 300°C. upwards: in Ticonal initial values are lower but remain almost constant up to about 600°C. For both alloys magnetostriction disappears in the region of 800°C. The experiments reported form part of a larger investigation being carried out jointly by the Permanent Magnet Association and the Electrical Research Association.

Ni-Span C in Filters

L. L. BURNS: 'A Band-Pass Mechanical Filter for 100 Kilocycles.' *R.C.A. Rev.*, 1952, vol. 13, Mar., pp. 34-46.

For an introduction to the subject reference is directed to an earlier paper by the author and his colleagues (*ibid.*, 1949, vol. 10, Sept., pp. 348-65), which contains a detailed theoretical discussion and some examples of experimental filters. Since 1949

considerable additional development has taken place, and recently a programme was initiated on design of filters suitable for single-side-band radio telephony, which would have a pass band in the region of 100 kilocycles. The present article describes a mechanical filter design considered to be potentially useful for many broadcast applications. For its construction temperature-stability was of prime importance, dictating the use of Ni-Span C or some other constant-modulus alloy. Ni-Span offers the added advantage of being magnetostrictive by virtue of its nickel content, and thus does not require nickel plating for electrical excitation. The constructional details of the filter are illustrated and its operation is discussed.

Nickel-containing Spring Materials

See abstracts on pp. 167 and 174.

CAST IRON

Self-Hardening Spheroidal-Graphite Cast Iron

M. BALLAY, R. CHAVY and J. GRILLIAT: 'A Study of Some Self-Hardening Spheroidal-Graphite Cast Irons.' *Revue du Nickel*, 1952, vol. 18, Apr., May, June, pp. 44-7.

Extended abstract of paper presented at International Foundry Congress, Brussels, Sept., 1951; see abstract in *Nickel Bulletin*, 1951, vol. 24, No. 12, p. 257.

Development of Spheroidal-Graphite Cast Iron in France

M. BALLAY, R. CHAVY and J. GRILLIAT: 'Study of Some Properties of Spheroidal-Graphite Cast Iron.' *Revue du Nickel*, 1952, vol. 18, Apr., May, June, pp. 36-44.

Reprint of main sections of paper presented before l'Association Technique de Fonderie, June, 1951; see abstract in *Nickel Bulletin*, 1951, vol. 24, No. 7, p. 153.

Determination of Magnesium in Spheroidal-Graphite Cast Iron

S. MAEKAWA: 'Determination of Magnesium in Nodular Cast Iron.' *Kinzoku (Metals)*, 1951, vol. 21, pp. 9-12. Essential details of procedure are given in *Chemical Abstracts*, 1952, vol. 46, Mar. 10, p. 1916.

Nickel-Alloy Cast Irons in Wear-Resisting Applications

E. J. BROWN: 'Castings to Resist Abrasive Wear.' *Foundry Trade Jnl.*, 1952, vol. 92, June 5, pp. 587-95.

The complex nature of wear is discussed and it is pointed out that hardness and resistance to corrosion are only two of the factors affecting wear-resistance. Although the specification of properties of wear-resisting materials is difficult, service experience has given practical indication of those which will give satisfactory behaviour and life in specific applications. Typical components in which wear-resistance is a factor of primary importance are discussed, with particular reference to those in which manganese steel, nickel-alloy cast irons, alloy steels and high-chromium irons have proved suitable. Applications of alloy cast iron in this field are legion, including parts used in many industries. Among castings in common use are liner plates, muller tyres, scrapers, skids, chutes, grinding balls, concaves, etc. It is urged that their use could be still further extended by development of improved forms of heat-treatment.

Some of the methods used for testing of the abrasion-resistance of the respective materials are described. The qualities of the steels and irons are reviewed and some account is given of methods of production, processing and heat-treatment generally used for development of optimum wear-resistance. Discussion on heat-treatment methods includes reference to the use of flame-hardening and nitriding, to obtain high surface hardness, and to the use of hard-facing by welding.

CONSTRUCTIONAL STEELS

Rare-Earth Additions to Nickel-containing Steels

W. E. KNAPP and W. T. BOLKCOM: 'Rare Earths Improve Properties of Many Ferrous Metals'. *Iron Age*, 1952, vol. 169, Apr. 24, pp. 129-34; May 1, pp. 140-3. *Part I*

The increasing use of rare-earth metals in steels and non-ferrous alloys is considered to be one of the major metallurgical developments of the past 18 months: important properties of many steels (constructional and stainless), and of high-temperature alloys, tool steels and electrical steels are now being improved by additions of $\frac{3}{4}$ to 6 tons of rare-earth metals per ton of ingots.

Cerium and lanthanum, added in the form of Mischmetall, have been the most widely used in this connexion, and it has been found that variations in the ratio of the individual rare-earth elements, especially of the two named, affect the degree of improvement brought about by such additions. High-lanthanum Mischmetall has proved to give better results than Mischmetall of ordinary composition, and work by the American Metallurgical Products Company has been devoted to developing a rare-earth mixture which will give optimum results at economic cost. The material recommended as a result of this work is now marketed as Lan-cer-amp.*

Laboratory and large-scale trials have established that Lan-cer-amp is a strong desulphurizer, but it is believed that this action is not the factor mainly responsible for the improvement in quality of steel resulting from the rare-earth additions. Information contained in this article, based on the literature of the rare-earth metals and on practical experience, suggests that the reactions of rare-earth elements with hydrogen and nitrogen may also be of considerable significance in explaining the beneficial influence of such additions. The rare-earth metals also react strongly with carbon: the nature of the reaction is discussed by the

* Trade mark of American Metallurgical Products Co., Pittsburgh, Pa.

present writers and it is concluded that 'it appears doubtful whether any large portion of the Lan-cer-amp addition is partitioned as carbides.' Oxides resulting from the reaction of rare-earth elements are stable and refractory and it is believed that the strongly deoxidizing action of Mischmetall and the high specific gravity of the resulting oxides were partially responsible for the failure of early investigators to appreciate the potentialities of rare-earth metal additions. It is considered, however, that when modern addition methods are used, the size and quantity of oxide-type inclusions in treated steels are quite comparable with those of untreated steels.

Part II

The second instalment of this article describes typical examples of improvements effected in the properties of various types of steel by treatment with Lan-cer-amp. Some of the main points are noted below:—

Small additions of Lan-cer-amp give consistently higher toughness and ductility values in steels quenched and tempered to a given level of hardness: this effect is illustrated by reference to a cast low-alloy chromium-nickel-molybdenum steel.

This treatment also improves low-temperature impact strength: in a wide range of low-alloy steels so treated the V-notch impact values at −40°F. (−40°C.) show an increase of 50 per cent. over those of untreated steels of similar types. Such additions also lower the impact-transition temperature.

Reports have been made of increased hardenability observed in steels treated with Lan-cer-amp, but it is considered that the data are at present insufficient to permit a balanced assessment of the effects of rare-earth metals on this property.

The beneficial effects mentioned above are found in cast, as well as in wrought steels, and it is also noted that the use of Lan-cer-amp improves fluidity and tends to reduce hot-tearing.

The presence of very small amount of rare-earth elements has been found to improve the high-temperature oxidation-resistance of chromium-nickel, chromium-nickel-iron, chromium-iron and iron-chromium-aluminium alloys: data reported by Hessenbruch are quoted by the present writers. There is also some indication that constructional alloy steels treated with rare-earth elements scale more slowly than untreated steels, and form a thinner, more closely adherent, scale.

A further practically useful effect of rare-earth metals is the increased hot-workability conferred on stainless steels (see *Jnl. of Metals*, 1951, vol. 3, pp. 973-977B; *Nickel Bulletin*, 1952, vol. 25, No. 1, pp. 21-2). The authors confirm, from experience with straight-chromium and high-speed steels, the improved yields reported earlier for rare-earth-treated austenitic steels. Refinement of grain is also associated with the use of Lan-cer-amp, in austenitic nickel-chromium and high-speed tool steels.

Elimination of hot-shortness has been achieved by Lan-cer-amp additions to an air-hardening steel containing nickel 3, molybdenum 7, chromium 3, carbon 0·60, per cent. and also 0·50 per cent. boron. A photomicrograph demonstrates the normal grain size and homogeneous structure obtained in rolled bar of this steel, despite the high boron content.

With regard to mode of treatment, the authors report that Lan-cer-amp is most effective when the steel heat has been made under strongly oxidizing conditions and, in basic electric-furnace practice, with minimum time under the reducing slag. It has been found much easier to make the correct addition of the rare-earth mixture in basic openhearth steels than under the conditions prevailing in the basic electric process. In production of stainless steels the practice of re-ladling gives results better than those obtained when a single ladle is used: the Lan-cer-amp is added to the second ladle, and a fluid, strongly basic, synthetic slag is used for covering. In basic openhearth steels the authors recommend as the most important features of good addition practice: 'a sizable carbon drop of at least 40 points, a short block not over 30 mm., 0·20 per cent. minimum of silicon in the furnace at tap, and a high lime-silica ratio, particularly on the ladle, after the Lan-cer-amp has been added'. When all the conditions are favourable, 1½ to 2 lb. per ton will give greatly improved impact and reduction-of-area values. In most stainless steels the best results can be obtained with 2-3½ lb. Lan-cer-amp per ton.

Restrictions on Use of Nickel: O.E.E.C. Action

See abstract on p. 171.

T-T-T Diagrams for Hypoeutectoid Nickel-Chromium-Molybdenum Steel

E. A. LORIA: 'Isothermal Transformation of Austenite in a Nickel-Chromium-Molybdenum Steel.' *Trans. Amer. Soc. Metals*, 1952, vol. 44, pp. 870-6.

The author presents data on the isothermal transformation characteristics and structural features of a steel of the following composition: carbon 0·32, nickel 2·35, chromium 0·75, molybdenum 0·52, manganese 0·58, silicon 0·30, vanadium 0·11, phosphorus 0·032, sulphur 0·020, per cent. The T-T-T diagram for this steel, together with that of a molybdenum hypoeutectoid steel, is presented and discussed. The diagram shows a full knee for the pearlite reaction and a second lower knee for the bainite reaction, separated by a bay of stable austenite. Effects of the alloying elements present in this steel and in some other low-alloy types previously studied by the author are discussed, in relation to their influence on the start of the transformation curves. For the steels under consideration ferrite is the initial decomposition product (and hence the primary factor influencing hardenability). The manner in which alloying elements may decrease the rate of nucleation and the rate of growth of ferrite is considered.

Isothermal Formation of Martensite in an Iron-Chromium-Nickel Alloy

See abstract on p. 179.

Isothermal Formation of Martensite in Nickel-Iron Alloy

See abstract on p. 174.

Burst Phenomenon in Martensitic Transformation

See abstract on p. 175.

Influence of Nickel on Hot-Shortness of Copper Steels

G. G. FOSTER and J. K. GILCHRIST: 'The Influence of Copper, Nickel and Tin on the Hot-Working Properties of Mild Steel. *Metallurgia*, 1952, vol. 45, May, pp. 225-30.

The steady increase, during recent years, in the amounts of residual elements present in mild steel has become so marked as to render advisable a re-examination of their effects on the hot-working properties of steel. The present report is concerned with an investigation (in the Research Department of Messrs. Babcock and Wilcox, Ltd.) of the occurrence of surface fissuring in mild steel, a phenomenon frequently associated with the presence of residual elements, notably copper and tin. (The term 'hot shortness' is used in this paper to denote surface fissuring developed during slow deformation: inherent brittleness occasioned by higher copper contents is not considered.)

The occurrence of the defect in copper-containing steels is widely recognized, but the existing literature, the main items of which are briefly reviewed by the authors, gives no fully satisfactory information on causative conditions, limits of residual elements producing the effect, and remedial measures. The authors of this paper report a systematic study of the influence of copper and of tin on the hot-working properties of mild steel, and of the corrective effect of nickel in copper-containing steels.

The form of test procedure used (180° hot-bend) was devised to permit of wide applicability, ready standardization and, so far as possible, quantitative evaluation of results. Test piece and apparatus are illustrated. Duplicate hot-bend tests were carried out on steels containing varying amounts of copper, tin, copper + tin, copper + nickel, and copper + nickel + tin, at each of six temperatures (50° intervals from 950° to 1200°C.). Graphs show results of visual examination of the specimens after test and the depth of fissuring resulting from bending at the respective temperatures.

The significant features of the observations made are in agreement with the generally accepted theory of the mechanism of surface fissuring during hot-working, which postulates formation of a copper-rich phase at the surface of the steel by selective oxidation, and subsequent penetration by the alloy during hot-working. With regard to the behaviour of the individual steels the following conclusions are drawn:—

(1) Copper, in the absence of nickel and tin, led to hot-shortness when above about 0·5 per cent. and at temperatures above 1000°C. At and below this temperature no hot-shortness was evident in steels containing up to at least 1 per cent. of copper. It is concluded that this transition temperature represents the melting point of a copper-rich phase containing other elements in solution.

(2) Addition of nickel to copper-bearing steels progressively raises the temperature at which hot-shortness appears, until with a nickel content double that of the copper, no evidence of hot-shortness was found, in the range of temperature investigated, for copper contents up to at least 0·9 per cent.

(3) Addition of tin to copper or copper-nickel steels led to hot-shortness at progressively lower copper contents, at all the temperatures used. In the presence of tin nickel became ineffective.

(4) In a few cases hot-shortness at 1000°C. was found in steels which behaved satisfactorily at all other temperatures within the normal test range. The reason for this anomaly is not yet clear.

(5) The results of this investigation are applicable primarily to hot-working processes involving bending, but probably do not apply in their entirety to processes such as rolling and tube piercing, where deformation is more rapid and of a different character. For evaluation of behaviour under these conditions the Ihrig hot-twist test would probably give more reliable indication.

(6) All tests reported in this investigation were conducted in air. Presence of sulphur would be expected to cause marked deterioration of hot-working properties, due to formation of sulphides in the scale, and in such case the presence of nickel would tend to be injurious rather than beneficial, owing to the low melting point of nickel sulphide.

High-Temperature Properties of Alloy Steels for Rocket Chambers

See abstract on p. 180.

Welding of Nickel-containing Steels and Alloys for Gas-Turbine Components

See abstract on p. 184.

Nickel-Alloy Steels in Wear-Resisting Applications

See abstract on p. 176.

HEAT- AND CORROSION-RESISTING ALLOYS

Constitution and Properties of Cast Heat-Resisting Nickel-Chromium-Iron Alloys

H. S. AVERY, C. R. WILKS and J. A. FELLOWS: 'Cast Heat-Resistant Alloys of the 21% Chromium-9% Nickel Type.' *Trans. Amer. Soc. Metals*, 1952, vol. 44, pp. 57-80; disc., pp. 80-8.

Final form, with discussion, of paper abstracted in *Nickel Bulletin*, 1952, vol. 25, No. 1, pp. 16-17.

J. H. JACKSON gave some results obtained at the Battelle Memorial Institute, during a research sponsored by the Alloy Casting Institute on the A.C.I. 21-9 type alloy. Particular attention is directed to the outstanding ductility of the alloy. Tests on as-cast specimens and specimens aged for 24 and 48 hours at 1400°F. (760°C.) have shown the H.F. 21-9 per cent. alloy to be more ductile than the H.H. type (chromium 25, nickel 12, per cent.) at intermediate temperatures.

Details were given of the test apparatus and technique used at Battelle for determination of susceptibility to thermal fatigue. Data on the behaviour of four types of heat-resistant nickel-chromium-iron alloy indicated the marked superiority of the 21-9 composition, and experience gained in applying the results of the test to field service confirms the laboratory findings.

A further contribution to the discussion, from R. D. WYLIE, reported short-time and creep tests carried out by Babcock and Wilcox Company, which confirm the authors' results. Wylie also discussed the retention of ductility in the aged 21-9 alloy, in comparison with that characteristic of 25-12 at the same carbon and nitrogen levels. It is suggested that the difference is probably attributable to difference in rate of rejection of carbon from the austenite in the two alloys. Some photomicrographs of alloys variously treated are presented in support of this view. Further discussion related to the structure of the alloy, as-cast and after long-time heating.

Nickel-Chromium Equilibrium Diagram

See abstract on p. 174.

Incoloy (Nickel-Chromium-Iron Alloy)

INTERNATIONAL NICKEL CO., INC.: 'Preliminary Report on Incoloy, a New Heat-Resisting Nickel-Chromium-Iron Alloy.'* *Published* 1952; 2 pp.

Incoloy has been developed to provide an 'economy' alloy giving good resistance to oxidation, and strength at elevated temperatures, combined with good workability and welding properties. Due to the need for economy in the use of nickel, preliminary information on this alloy is being released at once, but more comprehensive technical data will be available later as a result of further laboratory and field tests.

The composition limits of Incoloy are given below:—

	%
Carbon	0·10 max.
Manganese	1·50 max.
Sulphur	0·030 max.
Silicon	1·00 max.
Copper	0·50 max.
Nickel (plus cobalt)	30·00-34·00
Chromium	19·00-22·00
Iron	Remainder

The expansion coefficient of Incoloy compares favourably with that of Inconel, indicating that the alloy should have the same high level of resistance to cracking under drastic temperature changes. Its resistance to oxidation is also of the same order as that of Inconel. By virtue of its relatively high nickel content, Incoloy is stably austenitic, showing no tendency to become embrittled by precipitation of sigma or carbidic phases after prolonged exposure to intermediate elevated temperatures.

With regard to behaviour in high-temperature service, it may be anticipated that Incoloy, due to its reduced nickel content, will be *superior* to Inconel in resistance to sulphur attack, 'green rot' and molten cyanide salts; *comparable* to Inconel in resistance to oxidation and resistance to attack by fused neutral salts; *inferior* to Inconel in resistance to nitriding, and to attack by halogen gases and molten caustic. A programme of research is under way to obtain quantitative data on resistance of Incoloy to corrosion at high temperatures.

Mechanical properties typical of Incoloy in various forms and conditions were tabulated in *Nickel Bulletin*, 1952, vol. 25, No. 4, p. 111.

*Copies of this publication will shortly be available.

High-Temperature Properties of 16-25-6: Effect of Duration of Test

C. L. CLARK, M. FLEISCHMANN and J. W. FREEMAN: 'Influence of Extended Time on Creep and Rupture Strength of 16-25-6 Alloy.' *Trans. Amer. Soc. Metals*, 1952, vol. 44, pp. 89-108; disc., pp. 108-12.

Final form, with discussion, of paper abstracted in *Nickel Bulletin*, 1951, vol. 24, No. 11, pp. 243-4.

Discussion included two contributions urging the desirability of notched-bar rupture testing as a means of evaluating susceptibility to high-temperature service embrittlement; the importance of stress-rupture tests before and after long-exposure at high temperatures, and the influence of processing conditions on high-temperature properties, are emphasized.

Isothermal Formation of Martensite in an Iron-Chromium-Nickel Alloy

S. A. KULIN and G. R. SPEICH: 'Isothermal Martensite Formation in an Iron-Chromium-Nickel Alloy.' *Jnl. of Metals*, 1952, vol. 4, Mar. (*Trans. Amer. Inst. Mining and Metallurgical Engineers*), pp. 258-63.

An introductory survey of earlier researches on subzero isothermal formation of martensite is followed by a report of studies on an alloy of the following composition: chromium 14·38, nickel 9·06, carbon 0·008, manganese 1·21, silicon 0·36, nitrogen 0·034, per cent.

The experimental procedure (using wire specimens) involved:—

(1) Determination, by electrical-resistance measurements, of M_s temperature on slow cooling, using specimens which, after austenitizing at 1095°C. for 20 minutes, had been oil-quenched to room temperature and subsequently cooled at 1°-2°C. per minute.

(2) Study of isothermal martensite formation on samples having variable initial martensite contents (0-23 per cent.). The specimens were quenched to various sub-atmospheric temperatures and allowed to transform isothermally, electrical-resistance readings being taken as a function of time at temperatures of −18·5°, −28·5°, −38·5°, −78°, −122·5° and −196°C.

(3) Study of isothermal martensite formation on samples having constant initial martensite content (20·5 per cent.). The specimens used were quenched to −196°C. for 2 minutes and then held at −16·8°, −24·1°, −37·1° and −55·5°C. Electrical resistance was again determined as a function of time at temperature.

(4) Study of isothermal martensitic transformation occurring above M_s.

Summary of Conclusions resulting from the above experiments.

A distinguishing feature of the martensitic transformation in the alloy studied is the extensive isothermal transformation taking place at low temperatures. The observed M_s temperature of the alloy was found to depend on rate of cooling. Isothermal martensitic transformation takes place in this alloy at temperatures above the M_s temperature. The amount of martensite formed isothermally in a given time follows a C-curve behaviour with decreasing temperature. The curve of the initial rate of nucleation of isothermal martensite as a function of temperature has the same form as that obtained for ordinary nucleation and growth transformations. The transformation at low temperatures cannot be described in terms of the temperature dependence of the rate of growth. Initial martensite content, within the limits investigated, had no significant effect on initial rate of isothermal nucleation. It was found possible to obtain a greater amount of martensite by an isothermal treatment at a high temperature than could be produced by quenching to a very low temperature. Prequenching to −196°C., followed by isothermal transformation for 2 hours at a temperature below −30°C., resulted in less total transformation than could be produced by an identical isothermal treatment not preceded by the low-temperature quench. The authors urge that a general theory of martensite formation must not only include the basic concepts of the strain-embryo theory but also must allow for the important rôle of thermal fluctuations.

Sigma Formation in Nickel-Chromium Steels

M. E. NICHOLSON, C. H. SAMANS and F. J. SHORTSLEEVE: 'Composition Limits of Sigma Formation in Nickel-Chromium Steels at 1200°F. (650°C.).'
Trans. Amer. Soc. Metals, 1952, vol. 44, pp. 601-19; disc., pp. 619-20.

Final form, with discussion, of paper abstracted in *Nickel Bulletin*, 1951, vol. 24, No. 11, pp. 241-2.

S. J. ROSENBERG stated that work at the National Bureau of Standards, on 18-10 alloys of varying carbon content, had shown that even at a carbon content of 0·007 per cent. carbides were found to be present at 1200°F. (650°C.). Delta ferrite was also observed at that temperature in some of the alloys, but the indications were that this phase was not stable, tending to transform to sigma as equilibrium was approached.

High-Temperature Properties of Alloy Steels for Rocket Chambers

R. L. NOLAND: 'Strengths of Several Steels for Rocket Chambers subjected to High Rates of Heating.'
Jnl. Amer. Rocket Soc., 1951, vol. 21, Nov., pp. 154-62.

The author presents a summary of the results of two series of tests made to determine the tensile strengths of various types of steel when subjected to temperatures and rates of heating comparable to those encountered by the metal parts of solid-propellant rocket motors. The aerojet test apparatus designed for part one of the trials (by Aerojet Engineering Corporation, Azusa, California) is described and illustrated. It consists essentially of a gas-generating chamber where a solid propellant charge is burned, a test cylinder where the material under study is stressed and rapidly heated, and a nozzle section through which the generated gases are allowed to escape. By suitable selection of propellant and dimensions of gas passage, heating conditions imposed on the test cylinder can be held constant over a wide range of applied stress, or can be widely varied, at constant stress. The steels used as test cylinders were of the following types:—

A.I.S.I. A4130 chromium-molybdenum steel, in various conditions.
N.E. 8630 low-nickel-chromium-molybdenum steel; 150,000 p.s.i. (67 tons per sq. in.) tensile.
Boron-treated A.I.S.I. 1035 steel; 170,000 p.s.i. (76 tons per sq. in.) tensile.
Normalized tube steel.
A.I.S.I. 3140 nickel-chromium steel; 170,000 p.s.i. (76 tons per sq. in.) tensile.
A.I.S.I. C 1015 steel, in the cold-drawn condition, and intermittently welded.
A.I.S.I. 2330 nickel steel; 150,000 p.s.i. (67 tons per sq. in.) tensile.

Individual test data are reported for the respective materials, and a graph summarizes typical tensile strength *vs.* temperature values for all the steels, over the range 400°-1350°F. (205°-735°C.) approx.

A second series of experiments, made at Battelle Memorial Institute, comprised tensile tests with rapid rise of temperature, comparing specimens uniformly heated and those having temperature gradients through the cross sections. The procedure adopted made possible determination not only of temperature/strength values, but also of variation of modulus of elasticity with changes in temperature and stress conditions. In this series the steels used were:—

Uniloy 19-9DL chromium-nickel steel, tested in the stress-relieved condition.
A.I.S.I. 4130 chromium-molybdenum steel; 150,000 p.s.i. (67 tons per sq. in.) tensile.

The results of the whole series of tests indicate that time at temperature has a definite effect on high-temperature characteristics of the steels investigated. It is concluded that high-temperature strength properties based on relatively high-temperature exposure periods of the order of 15 minutes are conservative for design purposes when the service exposure times do not exceed 5 seconds.

Fabrication of N-155 Alloy: Problems and Their Solution

H. BROWN: 'Some Problems in the Fabrication of N-155 Alloy.' *Metal Progress*, 1952, vol. 61, May, pp. 67-72.

In the large-scale fabrication of many of the newly-developed high-temperature alloys problems have been encountered which were not anticipated on the basis of chemical composition or laboratory tests. This article discusses such practical difficulties in relation to the complex alloy N-155, for which the following limits of composition are given: carbon 0·08-0·16, nickel 19·00-21·00, chromium 20·00-22·50, cobalt 18·50-21·00, molybdenum 2·50-3·50, tungsten 2·00-3·00, niobium+tantalum 0·75-1·25, manganese 1·00-2·00, phosphorus 0·040 max., sulphur 0·030 max., nitrogen 0·10-0·20, silicon 1·00

max., per cent., iron remainder (about 30 per cent.).

Notes are given on occurrence, cause, and prevention of the following types of defect:—

Cracks in wrought dishpan-shaped parts, found to be associated with the presence of small stringers, which acted as stress-raisers. It is concluded that N-155 is more notch-sensitive than 18-8 stainless steel, in which the same defect did not appear under similar conditions of working. Since no suitable method of inspection has yet been found which can be used to detect the presence of the stringers before fabrication, it is concluded that the small percentage of parts having such defects must be accepted as a normal loss when using N-155 alloy for parts fabricated under the conditions described.

Cracks alongside welds, in tubing which had been heated to an intermediate temperature for bending. Investigation of failed parts, and associated experiments, led to the conclusion that N-155 passes through a hot-brittle range between about 1500° and 2100°F. (815° and 1150°C.). Working within this range of temperature should be avoided.

Variation in ductility values found between the tests made by vendor and purchaser of batches of N-155. These discrepancies were found to be due to differences in speed of testing used in the two laboratories, and to variations in the gauge of material on which elongation values were determined.

Sensitivity to variations in heat-treatment. N-155 alloy is more sensitive to variations in heat-treatment and pickling procedure than the austenitic nickel-chromium steels. Standard solution heat-treatment is at 2150°F. (1176°C.), and ductility progressively decreases with lowering of the solution-treatment temperature to 1950° and 1800°F. (1063° and 980°C.). Slow cooling sensitizes the alloy: stacking of parts should therefore be avoided, in order to avoid dead-air spaces.

Machining of High-Temperature Alloys

P. G. DEHUFF and D. C. GOLDBERG: 'Jet Alloys Toss Challenge to Machine Tools.' *Steel*, 1952, vol. 130, Apr. 28, pp. 76-8.

This article contains a survey, in somewhat general terms, of factors affecting the machining of the tougher alloys which have been developed for high-temperature service, and are now being used in parts of increasing size, produced to ever stricter tolerances. It is pointed out that seven factors have an immediate effect on production rate and quality of a completed part:- inherent machinability of the alloy; design of the part being fabricated; design and nature of the cutting tool; capacity and rigidity of the machine tool; accessory tooling; feeds and speeds; coolants. The influence of each of these variables is briefly discussed, and charts show (1) increase in tool life obtained by lowering the carbon content in a given alloy, and (2) the effect of cutting speed on tool life for five materials (Type 347 stainless nickel-chromium steel; Discaloy, in the solution-treated and the aged conditions; Refractaloy 26, also in the two conditions; a low-carbon titanium alloy of unspecified composition; and Inconel X, solution-treated).

Nickel-containing Materials in the Bristol 'Proteus'

'Bristol's New Proteus.' *Aeroplane*, 1952, vol. 82, June 6, pp. 685-95.

A detailed account is given of the Proteus 700 series, with particular reference to the 705, which is designed to power the production version of the Bristol 175 Britannia. The characteristics of the earlier Proteus engines are also recorded, including the 600 series, and the history of development of types currently under construction is outlined.

The 705 is a reverse-flow airscrew-turbine, and has a twelve-stage axial plus one-stage centrifugal compressor. Its eight combustion chambers are arranged radially round the compressor, and the engine incorporates the Bristol 'free-turbine' system, in which one turbine drives the compressor and another drives the airscrew. Both these turbines have two stages. Power and speed figures are given.

The following information is given with regard to materials of construction used in the 705:—In order to make the compressor as rugged as possible, to withstand the impact of ice or other foreign bodies, steel is now used for all the compressor blading, both for rotor and stator blades. Stator blades are of H.R. Crown Max complex heat-resisting nickel-chromium steel. These blades are forged or precision cast, but the rotor blades (in nickel-chromium tungsten steel to D.T.D. 282) are all forged. The combustion chambers have mild steel outer casings, and Nimonic flame tubes. First- and second-stage turbine wheels are in G. 18B steel, with Nimonic 80A rotor blades and Nimonic 80 stator blades. In the third and fourth stages the discs are of H. 46 ferritic high-chromium steel, with Nimonic 80 rotors and G. 18B stators. All the rotor blades are held in slots of 'fir-tree' cross section. The first three turbine stages have shrouded blades, but this is not regarded as necessary for the fourth stage.

The article is illustrated by numerous photographs of components, and by a three-page drawing of the 705 unit, which delivers 3,320 s.h.p., plus 1,200 lb. jet thrust for take off.

Inconel X Brake Springs in Aircraft

'Inconel X Brake Springs.' *Materials and Methods*, 1952, vol. 35, May, p. 111.

Under conditions involved in the landing of heavy bombers at about 110 miles per hour the temperature in the wheel brakes rises to about 1000°F. (540°C.). This short note describes (with illustration) a rotor brake made by Bendix Products, in which linked segments of metal revolve between stationary brake discs. The heat flows away in channels between the revolving, segmented discs. The return springs, which force the brake apart when pressure is released, are located in the hot parts of the assembly, and for this purpose Inconel X has been found especially suitable. Brakes of the types described are in service on airliners now in commercial passenger service.

Nickel-containing Spring Materials

See abstracts on pp. 167 and 174.

Ceramic Coatings for High-Temperature Applications

J. V. LONG: 'Ceramic Coatings.' *Machine Design*, 1952, vol. 24, May, pp. 122-6.

Describes the advantages of the Solaramic process for the protection of components working under high-temperature conditions, e.g., in gas turbines. The process was developed following extensive initial investigations on ceramic coatings carried out by the Bureau of Standards and the University of Illinois: see *Nickel Bulletin*, 1952, vol. 25, No. 2, p. 49. It is currently being used to protect combustion chamber liners, nozzle boxes, jet tailcones and other gas-turbine parts, making possible, in some cases, considerable saving in critical alloy elements, by facilitating use of coated low-alloy materials in place of higher-alloy materials which require large percentages of strategic elements. Typical examples are given.

Comparative oxidation-test results, on ceramic-coated and on uncoated alloys, are cited in support of the advantages of this form of protection, and design considerations involved in construction of coated components are discussed. The physical properties of such coatings, and methods of applying ceramics to steels and alloys and processing the coated articles are reviewed. Work in progress on further development of Solaramic coatings, to an extended range of metallic materials, is briefly outlined.

See also P. O'KEEFE: 'New Developments in Porcelain and Ceramic Coatings.' *Materials and Methods*, 1952, vol. 35, May, pp. 87-9.

Sulphidation of Nickel and Nickel Alloys at Elevated Temperatures

K. HAUFFE and A. RAHMEL: 'The Mechanism of the Sulphidation of Iron, Nickel and Nickel Alloys at Elevated Temperatures.' *Zeitsch. für physikalische Chemie*, 1952, vol. 199, Jan., pp. 152-69.

The paper opens with a summary discussion of sulphidation behaviour of copper and silver, the metals on which most investigations of this phenomenon have been carried out. A detailed report is then made of experimental work on iron (electrolytic and carbonyl grades), nickel, and nickel alloys containing, respectively, 0·1, 0·3, 0·5 and 1·0 at. per cent. silver, and 0·1, 0·5, 0·7 and 1·0 at. per cent. chromium. Rate of sulphidation was determined, on iron at 670°C. and on the nickel and nickel alloys at 630°C. and was correlated with sulphur vapour pressure. Sulphidation of iron was found to follow a parabolic time law: for nickel and nickel alloys the parabolic law did not apply, but an almost linear time-sulphidation relationship was found. In the case of nickel the change per unit of time and surface is independent of the thickness of the nickel sulphide film: the experimental observations are explained on the assumption of porous outer layer, which is also found in the case of the nickel-base alloys studied. The influence of sulphur vapour pressure on rate of sulphidation is interpreted as indicating that dissociation of the sulphur molecules into atoms of sulphur is the slowest of the processes involved in the total sulphidation reaction, and that it is therefore the determining factor from the time point of view. With constant sulphur vapour pressure and constant temperature conditions sulphidation, per given unit of time, increased with rise in silver content, whereas in the nickel-chromium series increasing chromium content was associated with slowing down of the sulphidation reaction.

Rare-Earth Additions to Nickel-containing Steels

See abstract on p. 176.

Chromium Carbide in Austenitic Chromium-Nickel Steels

A. B. KINZEL: 'Chromium Carbide in Stainless Steel.' *Jnl. of Metals*, 1952, vol. 4, May (*Trans. Amer. Inst. Mining and Metallurgical Engineers*), pp. 469-88; T.P. 3307 C.

Howe Memorial Lecture to the Institute, delivered Feb., 1952.

The paper is based on the results of extensive researches carried out in the Union Carbide and Carbon Research Laboratories. A brief introductory discussion of the significance of carbides in stainless steels is followed by a highly detailed report of a study of carbide precipitation in a commercial A.I.S.I. Type 304 steel of the composition carbon 0·07, manganese 0·49, silicon 0·33, nickel 9·34, chromium 18·91, nitrogen 0·033, per cent. Annealed specimens were subjected to precipitation treatments for 100 hours at 100°F. (56°C.) temperature intervals from 1000° to 1500°F. (538° to 815°C.), and for ten selected intervals ranging from 5 minutes to 64 hours, at the single temperature of 1300°F. (704°C.).

For initial study of the form of the carbides (particularly in relation to their mode and locale of precipitation), extractions were made from the treated samples, and were studied with the X-ray and the electron microscope: samples of the metal proper, and replicas of their surfaces, were prepared and examined with optical and electron microscopes. (Full details are given of the extraction methods used and of mode of preparation of the specimens for microscopical examination.)

The results obtained are reported at length, and are illustrated by a particularly fine series of optical and electron micrographs, demonstrating the condition of the specimens after the various treatments and their behaviour under nitric-acid and copper-sulphate intergranular corrosion-test conditions.

The author concludes that—

'Although the observations in this study are such as to require judgment and therefore in general do not constitute positive proof of any of the following conclusions, they are sufficiently clear and sufficiently quantitative in nature so that conclusions in the following may be accepted as inferences with a very high degree of probability as to validity.

'In the usual 18-8 type austenitic stainless steel with the carbon content somewhat greater than the limit of solid solubility, precipitation of chromium carbide $Cr_{23}C_6$ and only that carbide occurs at temperatures and time consistent with atomic mobility. The carbide precipitate is essentially two-dimensional in character and its shape is determined by the degree of registry of atomic planes intercepting the interface. At grain

boundaries carbides are precipitated in the form of dendroidal plate-like leaves. At twin ends they take the form of flat grids. At twin boundaries they are flat triangles. At twin planes or other locations within the grain they are primarily triangular and hexagonal plates. In annealed cold-rolled specimens subjected to precipitation treatment the carbides are in the form of elongated leaves. All this shows that the form of the carbide precipitate is a function of the nature and degree of registry of the lattice on either side of the interface in which the carbide forms.

'Knife-edge attack by nitric acid or acidified copper sulphate solution never occurs at both sides of a precipitated carbide. It occurs only on the side of least registry, reflecting high interfacial energy. This could result from strain, but could also be produced by other phenomena. Where time and temperature of precipitation are sufficient to allow stress-relieving or otherwise reduce lattice energy level on the less registered side of a carbide, there is no knife-edge attack adjacent to a carbide. Precipitation treatment for 100 hours at 1500°F. (815°C.) is typical of such a time-temperature condition.

'Elimination of knife-edge attack after all conditions of precipitation of the carbide is theoretically possible by providing suitable grain orientation. As yet we do not know how to accomplish this practically. However, it is hoped that the observations and hypotheses given in this paper will enable better planning in experimentation to design new stainless steel compositions affording greater economy in large industrial fields of application.'

Ferrite Formation in the Sensitizing Range in Austenitic Steels

E. J. DULIS and G. V. SMITH: 'Ferrite Formation Associated with Carbide Precipitation in 18-Cr/8-Ni Austenitic Stainless Steel.' *Trans. Amer. Soc. Metals*, 1952, vol. 44, pp. 621-32; disc., pp. 632-42.

Final form, with discussion, of paper abstracted in *Nickel Bulletin*, 1951, vol. 24, No. 11, p. 245.

Extensive discussion took place on martensite formation during cooling of 18-8 steels from the temperature at which carbides have been precipitated, and the influence of various elements on the M_s temperature.

Identification of Inclusions in Niobium-containing Nickel-Chromium Steel

E. J. DULIS and G. V. SMITH: 'Identification of 'Inclusions' in Austenitic 18 Cr- 8 Ni-Cb (Type 347) Steel.' *Trans. Amer. Soc. Metals*, 1952, vol. 44, pp. 877-81.

In 18-8 chromium-nickel steels containing niobium there occurs a characteristic microconstituent which, because it appears to remain largely inert and is seen in the unetched condition, may be called an 'inclusion', according to the common usage of that word. This paper reports an examination of the constituent in a steel of the following composition: carbon 0·07, manganese 1·21, phosphorus 0·014, sulphur 0·018, silicon 0·43, copper 0·02, nickel 10·80, chromium 17·10, niobium 0·99, tantalum 0·043, nitrogen 0·047, per cent.

Relatively large inclusions, present in the steel as quenched from a high temperature (2300°F. : 1260°C.), were investigated. They were concentrated at the surface by selective etching of the austenitic matrix for 30 hours in an alcoholic solution of picric and hydrochloric acids, after which they could be identified *in situ* by X-ray diffraction. Alternatively, they were concentrated by electrolytic dissolution of the matrix in 5 per cent. hydrochloric acid or by direct solution in strong hydrochloric acid, in which case they could be examined not only by X-ray diffraction, but also by chemical analysis.

The results reported show that the inclusions are essentially a solid solution of NbC and NbN, containing approximately equal amounts of carbon and nitrogen.

Resistance of Nickel-containing Materials to Phosphoric Acid

TENNESSEE VALLEY AUTHORITY: 'Development of Processes and Equipment for Production of Phosphoric Acid.' *T.V.A. Chemical Engineering Report No.* 2, 1948; 143 pp.

This report is the second in a series of publications describing the chemical-engineering activities of the Tennessee Valley Authority: it covers work done to develop and improve processes and equipment for production of phosphoric acid, for use in the manufacture of concentrated superphosphate and other phosphate fertilizers. The report contains drawings and descriptions of large-scale acid plants built and operated under the aegis of the Authority. Small-scale and pilot-plant investigations are also described, and data are presented on the properties of phosphorus, phosphorus pentoxide, and phosphoric acid. Results of corrosion tests which led to the selection of the materials of construction used in the larger-scale plants will be reported in a later publication, but the present report includes some information on experience in use of various metallic materials in the respective plants, and a table shows the corrosion rates of a wide range of metals and alloys in contact with superphosphoric acid at elevated temperature (465°F.: 240°C.). The materials on which information is given include many of the high-nickel corrosion-resisting alloys and various grades of austenitic nickel-chromium steel.

These data show that the Hastelloys (A, B, C and D), tantalum, sterling silver, Chlorimet 2 and La Bour R 55 had corrosion rates less than 50 mils penetration per year. It is considered that, from the standpoint of cost and ease of fabrication, Hastelloy B would be the most satisfactory material for use in a superphosphoric acid plant. Teflon was found to be suitable for use as a gasket material with Hastelloy B.

Stainless Steel for Bolting

M. GALLUP: 'Maintenance Expedited by Stainless Bolting.' *Metal Progress*, 1952, vol. 61, May, pp. 95-6.

The writer urges that although the use of stainless steel of certain types is now severely restricted, it should be widely adopted for bolts, due to the reduction in maintenance costs so effected in important production machinery. As an example, it is stated that in the works with which the writer is associated 16

man-hours were previously required to remove the spindle of one cutting machine for repair. Installation of stainless-steel parts and bolts has reduced this time to less than two hours. Another essential use for stainless-steel bolts is in furnaces; much difficulty and loss of time often arises from bolting of ordinary steel which has become locked in place by oxide or by stresses induced by the thermal conditions present. Change to stainless steel for many maintenance applications would, it is suggested, be justifiable in effecting important savings in labour and production time.

Welding of Nickel-containing Steels and Alloys for Gas-Turbine Components

A. J. ROSENBERG: 'Welding Characteristics of Materials for Aircraft Gas Turbines.' *Welding Jnl.*, 1952, vol. 31, May, pp. 407-12.

An essentially practical paper, based on experience of the General Electric Company, Lynn, Mass., in welding of sheet materials for gas turbines. The first section deals with substitution of 321 (titanium-stabilized) for 347 (niobium-stabilized) 18-8 chromium-nickel steel. For the welding of 321 niobium-stabilized or extra-low-carbon chromium-nickel steel electrodes have given good results: some success has also been achieved with an electrode of Type 316 (molybdenum-containing austenitic steel). For applications in which Type 321 does not provide sufficient strength at the operating temperatures involved, G.E.C. has successfully employed Timken 16-25-6, using a heavily coated electrode of the same material for welding the Timken sheet to itself, or to Types 347 or 321 steels. It is emphasized, however, that the 16-25-6 steel is not stabilized, and is consequently subject to intergranular corrosion after heating within the sensitizing range (1000°-1600°F.: 538°-870°C.). Caution is added that in the case of all austenitic steels which attain their maximum properties by cold working, welding results in a fully annealed cast structure and that the strength of the welded joint is therefore limited to that of annealed steel of the type involved.

Age-hardenable alloys (Inconel W and Inconel X) are next considered. When using some of the conventional austenitic stainless steel spot-weld settings, with normal electrode forces, excellent shear-test results are obtained in welds on these alloys, but there is a tendency to weld porosity or dendritic shrinkage. This tendency can be minimized by slow cooling of the weld, high unit forces or a combination of both. The use of medium- or low-conductivity electrodes, pulsation welding and high machine forces gives the balanced conditions producing optimum soundness and strength in spot welds in these alloys. Since in seam welding the wheels are cooled by a direct stream of water, it is impossible to arrange for very slow cooling, but slow rates of welding are found helpful, with high forces. No major difficulties have been found in inert-arc welding the Inconel alloys, provided that good metal backing or inert-gas backing is used. Welds made by this method meet bend-test requirements in both the as-welded and the age-hardened conditions. Direct ageing at 1300°F. (704°C.) after welding has been found to produce, in the welds, short-time properties comparable to those of the parent materials, but the stress-rupture values for the aged material are only about half those of the parent alloy. Treatment at a higher ageing temperature (1450°F. : 785°C.), for 2 hours, considerably raises the stress-rupture properties, but effects slight reduction in short-time values. This treatment is recommended by the General Electric Company for both spot welds and welds made by the inert-arc method. Metal-arc welding of the Inconel W and X alloys presents some difficulties, mainly due to the problem of slag removal: experiences with electrodes of Inconel and Inconel X are reported. The high electrical resistivity of Inconel X results in a tendency of the wire to overheat when welding at normal currents. Short-length electrodes should therefore be used, and minimum current.

Haynes Stellite No. 25 (nickel 9-11, chromium 19-21, tungsten 14-16, silicon 1·0 max., manganese 1-2, iron 2·0 max., per cent., cobalt balance) is one of the most easily welded of the high-temperature alloys. Metal-arc welding with No. 25 electrodes, inert-arc welding, and resistance welding, all give sound joints. Certain forming and machining problems have been encountered with this alloy, but are not discussed in the present paper. Haynes Stellite No. 88 has proved less satisfactory from a welding standpoint, due to cracking. This alloy contains chromium 12, nickel 15, boron 0·11, per cent., and it is thought that the boron content may account for the tendency to cracking. Work is still in progress at G.E.C. on the welding of this alloy.

For applications in the lower-temperature ranges, up to about 800°F. (425°C.), low-alloy high-tensile steels are being substituted, wherever possible, for the higher-alloy types. Among the steels used are N.A.X., Yoloy, Corten, N.E.S. 70, R.D.S. 50, and N.E. 8615. All can be successfully resistance welded, but, with the exception of Yoloy, a stress-relief treatment is essential. Metal-arc welding of the steels presents no problems of a particular nature, except that stress-relief is necessary. With inert-arc welds there is a tendency to porosity, and the process would appear to be unsuitable for use on these steels for high-quality applications. It is also not entirely satisfactory on S.A.E. 4130.

In view of the growing interest in titanium-containing materials for gas-turbine components, the author also discusses the welding qualities of three grades: (1) low-strength, unalloyed, commercially pure titanium; (2) oxygen-nitrogen and carbon alloys with titanium, which may be considered as low-strength alloy materials; and (3) high-strength alloys containing oxygen, chromium and iron or manganese plus aluminium.

'Sigma' Welding of Stainless Steels and Other Materials

R. T. BREYMEIER: 'Metal Transfer in Sigma Welding.' *Welding Jnl.*, 1952, vol. 31, May, pp. 393-9.

The paper contains results of a study (made by ultra-slow motion photography) of metal transfer in the arc, during welding by the sigma* welding process, under a variety of conditions of current, shielding gas

*Shielded-inert-gas-metal-arc.

and rod material. Materials on the welding of which information is given include steel, stainless steel, aluminium: general conclusions applicable to the welding of any type of material by this process are also recorded.

When sigma welding was first introduced best results were achieved by employing direct current of reverse polarity, but further investigation has shown that the use of straight polarity is not only feasible under certain conditions, but that for some applications it has definite advantages.

Additions of oxygen to argon have been found to have a pronounced effect on the metal transfer when welding some materials, and the introduction of a special mixture of high-purity oxygen and argon ('Linde's argon') has widened the range of applications of d.c. straight polarity considerably beyond those possible with either pure argon or helium. Effects of changes in composition of the gas, as well as of current direction, vary with the material welded. With regard to sigma welding of stainless steel the following conclusions are drawn:—

(1) A variation of bead width, penetration and metal deposition rates can be obtained by varying the current direction and the gas used as the shielding medium.
(2) Straight polarity produces higher metal-deposition rates for a given amperage.
(3) Sigma-grade argon makes the use of low currents feasible, particularly in conjunction with straight polarity.

The paper is illustrated by many photographs showing welds made in the steels and in aluminium under varying conditions of operation.

PATENTS

Extraction of Nickel from Sulphide Ores

Nickel and copper are recovered from sulphide ores by a process which comprises flash smelting of the sulphides in a furnace, to yield a matte rich in nickel and copper and an overlying slag containing appreciable quantities of nickel and copper. Subsequently or simultaneously finely divided iron sulphide is flash-smelted with a flux, to oxidize the slag part of the sulphide, and convert the remainder into molten drops of iron sulphide and these drops are allowed to fall through the slag and carry the nickel and copper content in it into the matte.

Pyrrhotitic ore containing nickel and copper sulphides is separated into a concentrate rich in nickel and copper and one rich in pyrrhotite, and the two concentrates are used as the starting materials in the process.

INTERNATIONAL NICKEL CO. OF CANADA, LTD.
Brit. Pat. 672,418.

Production of Metal Articles from Salts

Metal articles, especially those having shapes not easily made by powder metallurgy, are formed by pressing or casting to shape the metal salt (preferably a halide), chemically converting to metal, and finally compacting, with or without subsequent heat-treatment. The salt may be mixed with metal powders. In an example, plates of an alloy containing nickel 60, iron 20, molybdenum 20, per cent. are made by casting the mixed chlorides, reducing in hydrogen saturated with sodium vapour at 1300°-2000°F. (704°-1093°C.), washing with alcohol, hot-rolling, annealing in hydrogen, and finally cold rolling.

D. PRIMAVESI. *Brit. Pat.* 668,544.

Production of Nickel Catalysts

Catalysts are made by impregnating a carrier with an aqueous solution of either ammonium tungstate or ammonium molybdate and a cobalt or nickel salt. The formation of insoluble compounds is prevented by the presence of an alkanolamine, preferably mono-, di-, or tri-ethanolamine.

N.V. DE BATAAFSCHE PETROLEUM MAATSCHAPPIJ.
Brit. Pat. 668,592.

Production of Metal Powders

Powders having good sintering qualities are made by precipitating hydroxides of metals from solutions of their salts by means of ammonia or ammonium carbonate, and subsequently reducing them at an elevated temperature, preferably with hydrogen, and, if necessary, under pressure. In the production of powders of copper, nickel, cobalt and zinc it is preferable to re-dissolve the first precipitate with excess ammonia, filter off solid impurities, and re-precipitate by removal of ammonia.

BADISCHE ANILIN- UND SODA-FABRIK.
Brit. Pat. 672,354.

Production of Porous Metallic Parts

Porosity of shaped articles made by sintering magnetic metal or metallic oxide powders is increased by subjecting the powder to a magnetic field before or during sintering. The pore volume of a sintered accumulator plate of carbonyl-nickel powder can thus be increased from 80 to 84 per cent., effecting a 20 per cent. saving of nickel.

BADISCHE ANILIN- UND SODA-FABRIK.
Brit. Pat. 668,147.

Rare-Earth Additions to Nickel

Malleable nickel capable of being hot- and cold-worked, and suitable for vacuum-tube electrodes, is produced from electrolytic nickel by deoxidizing with Mischmetall or pure rare earths. The product should not contain more than 0·2 per cent. each of cerium and lanthanum.

F. E. BASH, assignor to DRIVER-HARRIS CO.
U.S. Pat. 2,586,768.

Nickel Undercoat in Silver Plating of Bearings

An adherent bond is obtained between silver and a steel backing, e.g., for bearings, by first coating the steel with nickel applied as powder (by brushing, spraying, or in a liquid binder), and fusing to the base by heating in an inert atmosphere.

J. B. BRENNAN. *U.S. Pat.* 2,580,652.

Stripping of Nickel Coatings

Copper, nickel, or chromium coatings are stripped from a ferrous metal base without etching the surface by making the article anode in an aqueous bath containing $NaNO_3$ (2 lb. per gal.-saturation), $NaNO_2$ (0·5-4 oz./gal.), NaOH (0·05-0·5 oz./gal.), NaCl as impurity in the $NaNO_3$ (about 0·25 oz./4 lb. $NaNO_3$). The bath is operated at 100°-220°F. (38°-105°C.), with a current density of 50-150 amp./sq. ft.

G. T. LARSEN, assignor to GENERAL MOTORS CORPN. *U.S. Pat.* 2,581,490.

Nickel-Aluminium Bronze for Engineering Parts

An alloy of the composition shown below is suitable for use, in the forged state, for engineering parts operating at temperatures of the order of 300°-350°C. (e.g., gas-turbine compressor blades). The alloys are claimed to show a good combination of resistance to corrosion, creep and fatigue. Composition limits and preferred range, in brackets: aluminium 5-12 (6-8), titanium 1-4 (1-1·5), nickel 0-10 (5-7), iron 0·1-7 (2-4), per cent., copper balance.

The preferred treatment is soaking at 900°-1000°C. for 12 hours to ½ hour; cooling in air, oil or water; ageing at 400°-600°C. for 32 hours to 1 hour.

ROLLS ROYCE, LTD. (inventors: H. E. GRESHAM, R. CALVERT and D. W. HALL). *Brit. Pat.* 672,263.

Nickel-Iron-base Spring Alloys

Alloys stated to be specially suitable for springs contain nickel 36·9-37·6, chromium 7·5-9, beryllium 0·8-1·2, titanium 0·8-1·2, manganese 0·6-1·1, silicon 0·1-0·3, per cent., balance iron.

HERAEUS VACUUMSCHMELZE, A.G. (inventor: W. HESSENBRUCH). *German Pat.* 751,177.

Nickel-Chromium Steel Electromagnetic Recording Wire

Wire suitable for electromagnetic recording is made from steel containing nickel 8-12, chromium 17-20, carbon 0·06-0·12, per cent., remainder iron. The steel is hot-rolled to rod, and subsequently alternately annealed and cold-drawn, in several steps, to a diameter of 0·020-0·008 in., giving a wire which has a substantially meta-stable austenitic structure. The wire is then annealed at 15°-1850°F. (−9·5°-1008°C.). Total reduction of at least 70 per cent. in the sectional area of the wire is effected by further 'cold-drawing', in 17 drafts, while the wire is kept in a medium maintained at 115°-190°F. (47°-88°C.). 'Cold-drawing' finishes the wire at a diameter of 0·006-0·003-in., producing a material having a fine precipitate of chromium-iron carbide and ferrite dispersed throughout its austenitic matrix, and showing a coercive force of 160-450 oersted, and a residual induction of 1500-6000 gauss.

C. H. CAMPBELL, R. E. GRIFFITHS and W. T. CRAMER, assignors to AMER. STEEL AND WIRE CO. OF NEW JERSEY. *U.S. Pat.* 2,578,782.

Addition Alloys for Production of S.G. Iron

Addition alloy for making S.G. cast iron comprises magnesium 12-30 (preferably 14-18), silicon 10-45 (preferably 27-33), carbon 0 up to solubility limit in the molten alloy, nickel balance, at least 35 per cent. Some of the nickel may be replaced by cobalt up to 0·5, iron up to 3, manganese up to 2, molybdenum up to 1, chromium up to 1, calcium up to 3, aluminium up to 2 per cent., and copper up to half the nickel content, provided that at least 35 per cent of nickel is present.

MOND NICKEL CO., LTD. (inventor: A. D. BUSBY). *Brit. Pat.* 671,463.

A further patent specifies an addition alloy containing magnesium 7-17, silicon 55-70, per cent., balance iron.

Some of the iron may be replaced by not more than 30 per cent. copper, not more than 5 per cent. manganese, not more than 1 per cent. calcium, not more than 1 per cent. aluminium, provided that at least 5 per cent. of iron is present. The alloy may contain carbon in solution.

MOND NICKEL CO., LTD. (communication from INTERNATIONAL NICKEL CO., INC.) *Brit. Pat.* 672,618.

Magnesium Treatment for Production of Compacted Flake-Graphite Cast Iron

Alloyed or unalloyed graphitic cast iron to which magnesium is added before casting is characterized by the fact that the iron as cast contains 0·02 to 0·04 per cent. magnesium and that substantially all the graphite is present in a more rounded and shorter form than ordinary flake graphite. The patent covers the method of producing such iron by adding magnesium to the melt, inoculating the melt, and casting shortly afterwards.

MOND NICKEL CO., LTD.
Brit. Pat. 671,467. (Corresponding to *U.S. Pat.* 2,485,761.)

Hardening of Nickel-Alloy Cast Iron

Grey cast iron containing carbon 2·25-3·25, nickel 7-10·5, copper 3-4·7, chromium 1-4, silicon 1·5-3, manganese 0-1, per cent., balance iron, is hardened by sub-zero treatment. Quenching from 1600°-1800°F. (870°-980°C.), down to below 900°F. (482°C.), machining, and then cooling to below −70°F. (−57°C.) generally gives a Brinell hardness of 450-575.

MOND NICKEL CO., LTD.
Brit. Pat. 669,799. (Corresponding to *U.S. Pat.* 2,567,791.)

Production of Improved Surface in Nickel-Alloy Steel Ingots

Improved surface is obtained in ingots by casting into moulds lined with a shell of silicate material having a melting point below the pouring temperature of the metal. Sodium silicate and mixed calcium-magnesium-aluminium silicates are suitable. The method can be used successfully for casting low- and high-nickel alloy steels, high-chromium steels and corrosion-resisting nickel-molybdenum-base alloys.

LINDE AIR PRODUCTS CO., assignees of H. E. KENNEDY. *Brit. Pat.* 669,939.

Long-Life Electrical-Resistance Alloys

Small amounts of rare-earth metals are added to alloys containing nickel 50-70, chromium 10-25, calcium 0·01-0·20, aluminium 0·01-1·0, per cent., balance iron. Life of wires made from these alloys is claimed to be of the order of 500-700 hours.

J. M. LOHR, assignor to DRIVER-HARRIS CO.
U.S. Pat. 2,581,420.

Ageing and Mechanical Treatments for Heat-Resisting Nickel-Chromium Steels

The complex nickel-chromium steels covered by *British Patent* 647,701 (see *Nickel Bulletin*, 1951, vol. 24, No. 4, p. 93) are subjected to ageing heat-treatment at 600°-900°C., the optimum treatment being 20 hours at 800°C. The ageing treatment may be applied after soaking just below melting point, as specified in *Brit. Pat.* 657,021. Articles made by this process have high resistance to creep and increased low-temperature proof-stress values. They are suitable for gas-turbine parts and similar applications.

According to a related patent the nickel-chromium-base steels covered by 647,701 are subjected to mechanical working at a temperature between 600° and 800°C. and subsequently soaked at a temperature 20°-150°C. below their incipient melting point. Steels so processed have high resistance to creep.

A further patent specifies that such steels be cold-worked after heat-treatment at 20°-150°C. below their incipient melting point. Such modification of treatment results in increased hardness and proof-stress values, with possibly some reduction in resistance to creep.

WILLIAM JESSOP AND SONS, LTD. (inventors: D. A. OLIVER and G. T. HARRIS).
Brit. Pats. 670,686; 670,687; 670,688 (additions to 647,701).

Forgeable Age-Hardening Heat-Resisting Steels

Forgeable age-hardening steels contain nickel 20-30, chromium 16-22, tungsten and molybdenum 3-15 each (10-20 combined), carbon 0-0·3, manganese 0-2, silicon 0-2, titanium 0-2, niobium 0-1, vanadium 0-3, per cent., balance iron. Cobalt is *not* present. For steels of preferred composition the 100 hours stress-to-rupture values at 1500°F. (815°C.) are stated to be at least 1500 p.s.i. (6·7 tons per sq. in.).

P. PAYSON, assignor to CRUCIBLE STEEL CO. OF AMERICA.
U.S. Pat. 2,587,613.

Creep-Resisting Nickel-Chromium Steels

Steels suitable for high-temperature applications, particularly I.C. engine valves and gas-turbine blades, contain carbon 0·08-1, silicon 0·1-2, manganese 0·1-2, nickel 5-30, chromium 30-5, tungsten and/or molybdenum 0·05-10, niobium (with or without tantalum) 0·05-15, vanadium 0·05-5 (niobium+tantalum+vanadium over 3 per cent.), cobalt 3-30, iron not less than 33, per cent. The steels may also contain aluminium 0·03-30, with or without copper 0·05-15, and nitrogen 0·06-0·30, per cent. Preferred compositions within these ranges are given. (Steels claimed in Brit. Pat. 647,701 are disclaimed: for details of this earlier patent see *Nickel Bulletin*, 1951, vol. 24, No. 4, p. 93.)

WILLIAM JESSOP AND SONS, LTD. (inventors: D. A. OLIVER and G. T. HARRIS).
Brit. Pat. 670, 555.

Complex Austenitic Nickel-Chromium Creep-Resisting Steels

Austenitic nickel-chromium steels having high creep-resistance at 750°C. contain carbon 0·08-1·0, silicon 0·1-2·0, manganese 0·1-5·0, nickel 5-30, chromium 5-14, tungsten and/or molybdenum 0·05-15, niobium and/or tantalum 0·25-15, vanadium 0-10, titanium 0-3, cobalt 3-20, nitrogen 0-0·3, copper 0-6, boron 0·001-0·5, iron not less than 33, per cent. The preferred composition is carbon 0·4, silicon 1·0, manganese 0·8, nickel 13·0, chromium 13·0, tungsten 2·5, molybdenum 2·0, niobium (with or without tantalum) 3·0, copper 10·0, nitrogen 0·04, boron 0·001-0·5, per cent., iron balance.

WM. JESSOP AND SONS, LTD. (inventors: G. T. HARRIS and H. C. CHILD).
Brit. Pat. 668,889.

Nickel alloy steels showing high resistance to creep at temperatures up to 700°C. are characterized by the absence of cobalt and niobium and the presence, as essential constituents, of carbon 0·08-0·40, silicon 0·10-1·0, manganese 0·20-3·00, chromium 9-17, nickel 7-12, molybdenum 1·75-3·0, copper 1-4, titanium 0·25-1, per cent., balance iron. Tungsten, 0·25-3·0 per cent., may also be present.

FIRTH VICKERS STAINLESS STEELS, LTD. (inventors: H. W. KIRKBY and C. SYKES).
Brit. Pat. 669,131.

Creep-Resisting Nickel-Chromium-Cobalt Alloys

The alloys covered, which are suitable, *inter alia*, for gas-turbine parts, fall within the following range of composition:—carbon 0·2-0·6, manganese 0·3-2, silicon 0·2-2, nickel over 20 and up to 30, chromium 10-20, cobalt 29-45, molybdenum 0·5-3, niobium 0·5-3, vanadium 0·1-6, iron 0-39·2, per cent.

A billet is forged by stamping in a die or dies (preferably at 1000°-1300°C.), cooled, soaked at a temperature 20°-150°C. below the incipient melting point, but above 1275°C., cooled, and warm-worked by stamping in a die or dies, preferably at 600°-900°C. The warm-working may be replaced by ageing, preferably at 600°C. for 10-500 hours.

WILLIAM JESSOP AND SONS, LTD. (inventors: D. A. OLIVER and G. T. HARRIS).
Brit. Pat. 670,560.

Alloys showing high resistance to creep at temperatures up to 750°C. contain chromium 15-20, nickel 0·05-12, molybdenum 2-5, tungsten 0-5, copper 1·5-3·5, cobalt 7-50, per cent. Titanium 0·25-1·5 per cent. is also present, being interchangeable with niobium 0·5-3 per cent.: maximum titanium+niobium is specified as 4 per cent. The following elements are also present:—aluminium 0·05-1, boron 0·002-0·5, carbon 0·10-0·5, silicon 0·10-1·5, manganese 0·20-2, per

cent., balance (at least 10 per cent.) iron. Vanadium, 0·1-3 per cent., is optionally present.
FIRTH VICKERS STAINLESS STEELS, LTD. (inventors: H. W. KIRKBY and C. SYKES).
Brit. Pat. 669,579.

Oxidation-Resisting Carbide/Metal Materials

Materials characterized by high strength and oxidation-resistance at temperatures up to 1315°C. comprise a carbide phase (preferably at least 80 per cent. titanium carbide) bonded, but not alloyed, with preferably 15-40 per cent. of an oxidation-resistant alloy, e.g., nickel-chromium-cobalt. The carbides may be sintered and then infiltrated with the bonding alloy, or the whole may be mixed as powders and sintered: typical compositions are cited. Materials of this nature are suitable for gas-turbine blading.
METRO-CUTANIT, LTD. *Brit. Pat.* 669,588.

'Infiltrated' Turbine-Blading Alloys

Turbine blades are formed of sintered porous skeletons of powdered material of high melting point (e.g., tungsten, molybdenum, titanium, tantalum, niobium, chromium, zirconium or their alloys or compounds), permeated throughout with a corrosion-resistant infiltrant, and having a fused-on coating of the infiltrant. Preferred skeletons are carbide or carbide/metal mixtures, and infiltrant materials are cobalt-, nickel-, or chromium-base alloys. Typical compositions are cited.
C. G. GOETZEL and J. L. ELLIS, assignors to SINTERCAST CORPN. OF AMERICA. *U.S. Pat.* 2,581,252.

Powder-Cutting of Nickel and Nickel Alloys

In powder-cutting metals such as nickel, nickel-base alloys, copper-base alloys and tungsten steels, the powder used consists of aluminium 10-65 per cent., balance iron. Separate pre-heating is not required and advantages are claimed over iron or iron-manganese powder.
LINDE AIR PRODUCTS CO. *Brit. Pat.* 671,863.

Silver-Palladium-Manganese Solders

Alloys of chromium or chromium and iron with nickel and/or cobalt are soldered with ternary alloys containing silver 36-98, manganese 1-20, palladium 1-50, per cent. The preferred composition is silver 75, palladium 20, manganese 5, per cent.
MOND NICKEL CO., LTD. (inventors: E. C. RHODES and D. W. RHYS). *Brit. Pat.* 671,072.

Alloy for Dental Fillings

An alloy of the following composition is claimed to harden, in 48 hours at room temperature, to 80-150 Brinell: nickel 49-74, gallium 25-45, silicon 0·5-7·5, per cent.
J. P. LYLE, assignor to ALUMINUM CORPN. OF AMERICA. *U.S. Pat.* 2,585,393.

An up-to-date list of addresses of publishers of the periodicals mentioned in The Nickel Bulletin has just been printed and we shall be pleased to send a copy to readers on request.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

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